RESTRICTED

ARTHROPODS OF MEDICAL IMPORTANCE WITH SPECIAL REFERENCE TO MALARIA CONTROL

NAVAL MEDICAL SCHOOL
NATIONAL NAVAL MEDICAL CENTER
BETHESDA, MARYLAND

1944

Date Due

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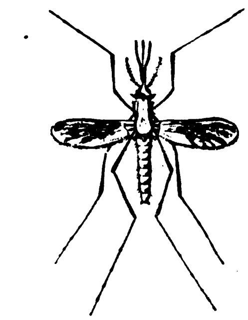
COMMON NAMES OF ARTHROPODS OF MEDICAL IMPORTANCE

Common Name		Scientific Group
Assassin bug	-	Reduviidae
Bedbug	-	Cimicidae
Biting midge	-	Ceratopogonidae
Blue bottle fly	-	Diptera
Black fly	-	Simuliidae
Blowfly	-	Diptera
Buffalo gnat	-	Simuliidae
Bugs (true)	-	Hemiptera
Centipede	-	Myriapoda
Chigger	-	Acarina
Chigoe	-	Siphonaptera
Cockroach	-	Orthoptera
Conenose bug	-	Reduviidae
Cootie	-	Anoplura
Crab louse	-	Anoplura
Crab	-	Crustacea
Crayfish	-	Crustacea
Deer fly	-	Tabanidae
Dog fly	-	Diptera
Eye gnat	-	Diptera
Flea	-	Siphonaptera
Flesh fly	-	Diptera
Fly	-	Diptera
Green bottle fly	-	Diptera
Horn fly	-	Diptera
Horse fly	-	Tabanidae
House fly	-	Diptera
Itch mite	-	Sarcoptidae
Jigger	-	Siphonaptera
Kissing bug	-	Reduviidae
Latrine fly	-	Diptera
Louse	-	Anoplura
Mango fly	-	Tabanidae
Millipede	-	Myriapoda
Mite	-	Acarina
Mosquito	-	Culicidae
Moth fly	-	Psychodidae
Muscoid fly	-	Diptera
No-see-um	-	Ceratopogonidae
Owl fly	-	Psychodidae
Punkie	-	Ceratopogonidae
Red bug	-	Trombidiidae
Sand flea	-	Siphonaptera
Sand fly	-	Psychodidae Ceratopogonidae
Scab mite	-	Sarcoptidae
Scorpion	-	Scorpionida
Screw worm fly	-	Diptera
Seam squirrel	-	Anoplura
Spider	-	Araneida
Stable fly	-	Diptera
Tick	-	Acarina
Tsetse fly	-	Diptera

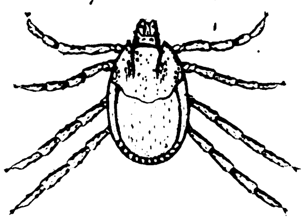
PLATE I.

TYPES OF ARTHROPODS TRANSMITTING HUMAN DISEASES



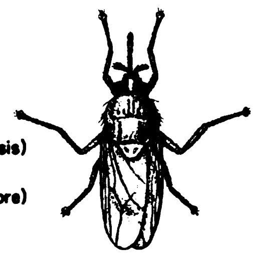
MOSQUITOES
transmit
Malaria
Yellow Fever
Dengue
Filariasis (Bancroft's)
Encephalitis

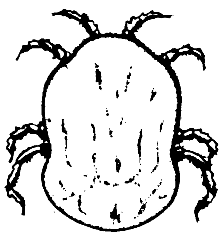
FLEAS
transmit
Plague
Endemic Typhus
Dog Tapeworm



"HARD" TICKS
transmit
Tick-Borne Rickettsioses
(Rocky Mt. Spotted Fever)
(Brazilian Spotted Fever)
(Fiévre Boutonneuse)
(So. African Tick Fever)
("Q" Fever)
Tularemia

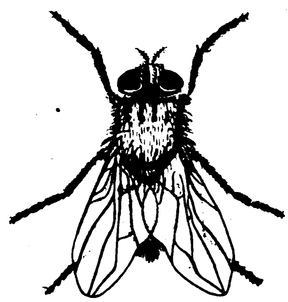
SKIN-PIERCING FLIES
transmit
Tularemia
Sand-fly Fever
Filariases (Loaiasis, Onchocerciasis)
African Sleeping Sickness
Leishmaniases (Kala-azar, Oriental Sore)
Bartonellosis

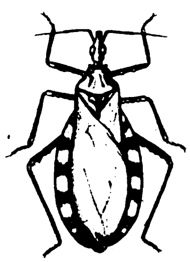




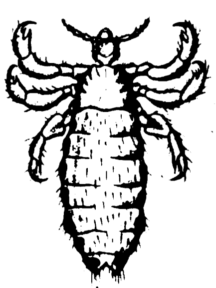
"SOFT" TICKS
transmit
Relapsing Fever

NON-PIERCING FLIES
transmit
Yaws
Typhoid Fever
Dysentery
Cholera
Conjunctivitis



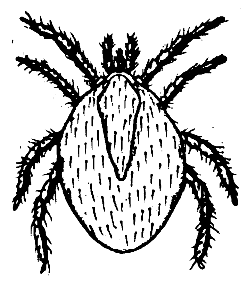


CONENOSE BUGS
transmit
Chagas' Disease



LICE
transmit
Louse Relapsing Fever
Epidemic Typhus Fever
Trench Fever

MITES
transmit
Tsutsugamushi
(Scrub Typhus)



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SECTION I. INTRODUCTION

HOW ARTHROPODS AFFECT THE HEALTH OF MAN

The arthropods of medical importance affect the health of man in the following ways:

1. By transmitting the agents of disease. There are two means by which this is accomplished.

   A. Mechanical transmission, in which arthropods may act as passive carriers of pathogenic agents - bacteria, viruses, protozoa.

   B. Biological transmission, in which arthropods act as essential hosts of the pathogenic agent, in addition to transporting it. Propagative or cyclical changes, or both, take place in the arthropod's body. Three types of biological transmission are recognized:

      (1) Propagative: The organisms undergo no cyclical changes, but multiply as in culture tubes. Examples: Plague, tularemia, typhus, spotted fever, yellow fever, dengue.

      (2) Cyclo-propagative: The organisms undergo cyclical changes and multiply in the process. Examples: Malaria, trypanosomiasis, leishmaniasis.

      (3) Cyclo-developmental: The organisms undergo developmental changes but do not multiply. Examples: Filariases.

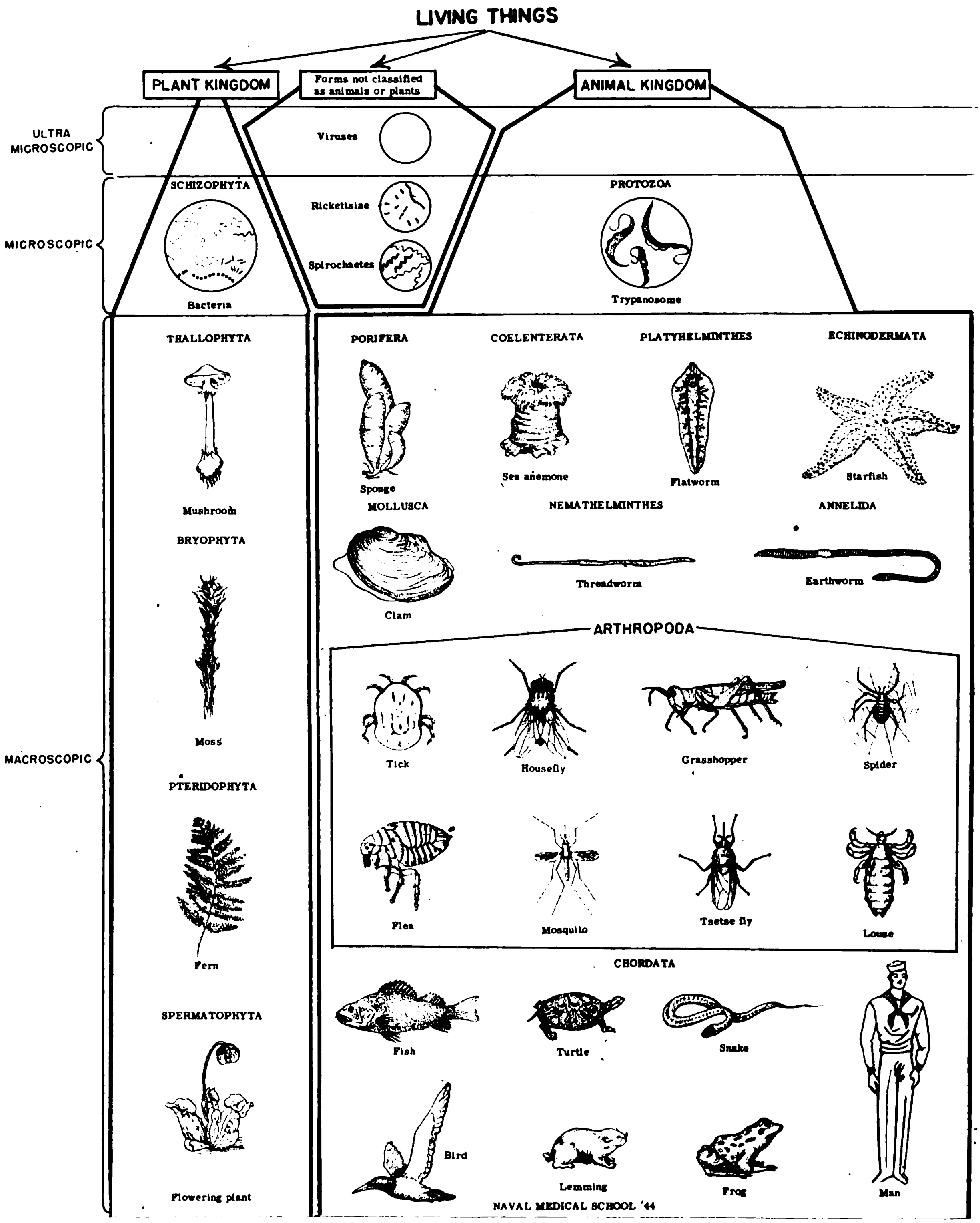
2. By invading the tissues of man. Arthropods may burrow into the skin, or live in the intestine or nasal sinuses. Examples: Scabies, in which the itch mite invades the skin; or myiasis, in which fly larvae develop in the skin or accessible body cavities.

3. By inoculating poisonous substances. Example: The bite of the black widow spider.

4. By being pests of man. Arthropods may bite or cause excoriation of the skin, with resultant discomfort. Example: Bedbug bites.

Of these various ways in which arthropods may adversely affect the health and well-being of man, by far the most important is their ability to transmit diseases. The types of arthropods which play this important role and the diseases which they transmit are shown in the accompanying plate. Attention in this manual will be centered largely on these disease-conveying arthropods. Human diseases and their more common arthropod vectors are summarized at the conclusion of the manual.

PLATE II.


LIVING THINGS
PLANT KINGDOM
Forms not classified as animals or plants
ANIMAL KINGDOM
ULTRA MICROSCOPIC
MICROSCOPIC
MACROSCOPIC
Viruses
SCHIZOPHYTA
Bacteria
Rickettsiae
Spirochaetes
PROTOZOA
Trypanosome
THALLOPHYTA
Mushroom
BRYOPHYTA
Moss
PTERIDOPHYTA
Fern
SPERMATOPHYTA
Flowering plant
PORIFERA
Sponge
COELENTERATA
Sea anemone
PLATYHELMINTHES
Flatworm
ECHINODERMATA
Starfish
MOLLUSCA
Clam
NEMATHELMINTHES
Threadworm
ANNELIDA
Earthworm
ARTHROPODA
Tick
Housefly
Grasshopper
Spider
Flea
Mosquito
Tsetse fly
Louse
CHORDATA
Fish
Turtle
Snake
Man
Bird
Lemming
Frog
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ORIENTATION OF THE ARTHROPODS AMONG LIVING THINGS

All living organisms are sorted into groups or divisions according to their morphological similarities. The first division is into kingdoms. Most living things fall either into the Animal Kingdom or the Plant Kingdom, although there are some living things (viruses, rickettsiae, spirochaetes) which cannot be assigned definitely to either kingdom. Each kingdom is further divided into phyla (singular phylum), classes, orders, families, genera (singular genus), and species. The species is the basic unit in classification and is defined as a group of similar individuals which can couple with each other and produce fertile young. In referring to any living thing, two names (generic and specific) are employed. The scientific name of man is Homo sapiens, Homo being the generic name and sapiens the specific. The genus Homo has only one species and, therefore, is said to be monospecific.

To illustrate this system, three living things are classified below:

	Man	A Malarial Mosquito	A Malarial Organism
KINGDOM	Animal	Animal	Animal
PHYLUM	Chordata	Arthropoda	Protozoa
CLASS	Vertebrata	Insecta	Sporozoa
ORDER	Mammalia	Diptera	Haemosporidia
FAMILY	Hominidae	Culicidae	Plasmodidae
GENUS	Homo	Anopheles	Plasmodium
SPECIES	sapiens	punctulatus	vivax

Biologists recognize five phyla of plants and twelve phyla of animals. Some of these are illustrated on the accompanying chart which also serves as a guide in orienting the taxonomic position of the phylum ARTHROPODA.

GENERAL CHARACTERISTICS OF THE ARTHROPODS

An arthropod is a segmented, bilaterally symmetrical animal possessing a hard exoskeleton and jointed appendages. All of these diagnostic characters are seen in the centipede figured below.

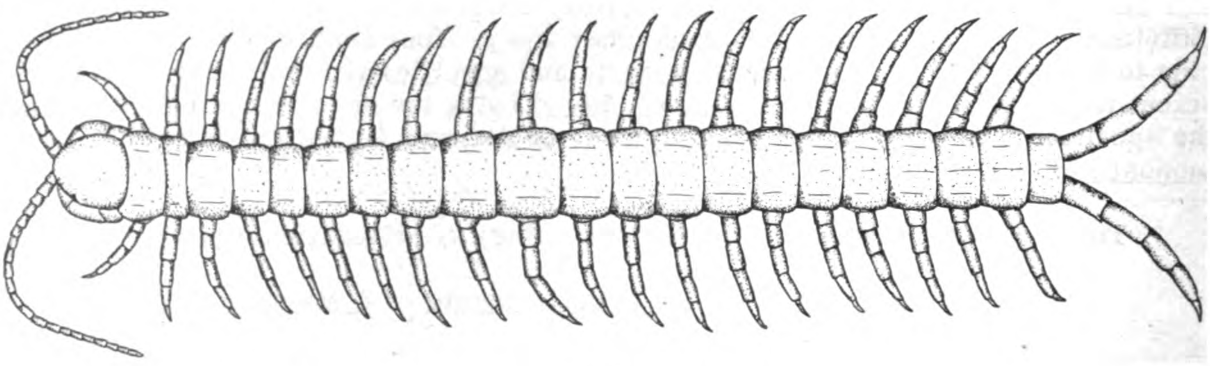


FIG. 1. A centipede, showing its body segments, bilateral symmetry, hard exoskeleton, and paired, jointed appendages.

The segments into which an arthropod's body is divided are grouped characteristically in the various classes. The centipede illustrates a generalized arthropod in which only the segments of the head have been so fused as to obscure the external evidence of segmentation.

Symmetry may be defined as the balanced orientation of body parts. In the great majority of animals, two general types are common -- radial and bilateral.

Animals which possess radial symmetry have their body parts arranged radially around a central axis like the parts of a cylinder or spindle. Any radial cut through this central axis will divide the animal into identical halves. Sessile animals or those which move about infrequently usually show this type of symmetry.

Animals with bilateral symmetry have their body parts arranged equally on the right and left sides of a dorso-ventral plane running the length of the body; and it is only along this one plane that a cut will divide the body into two equal parts, each of these parts being a mirror-image of its mate.

GENERAL CHARACTERISTICS OF THE ARTHROPODS

All arthropods are bilaterally symmetrical, but this is not an exclusive diagnostic feature, since almost all freely moving animals possess this type of symmetry.

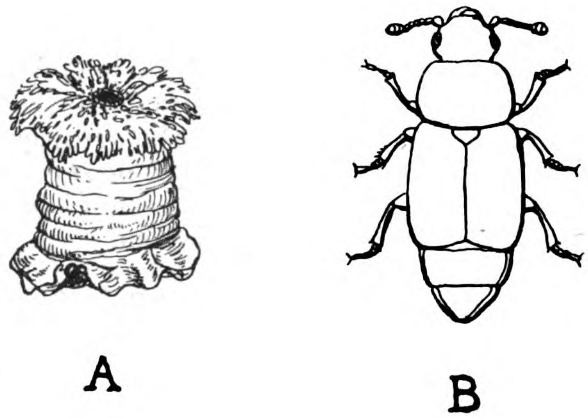


FIG. 2. Types of Symmetry. A. Sea anemone, a radially symmetrical animal. B. Beetle, a bilaterally symmetrical animal.

The supporting framework of an arthropod's body is on the outside and is referred to as an <u>exoskeleton.</u> In higher animals, such as the vertebrates, the supporting framework is internal and is referred to as an <u>endoskeleton.</u>

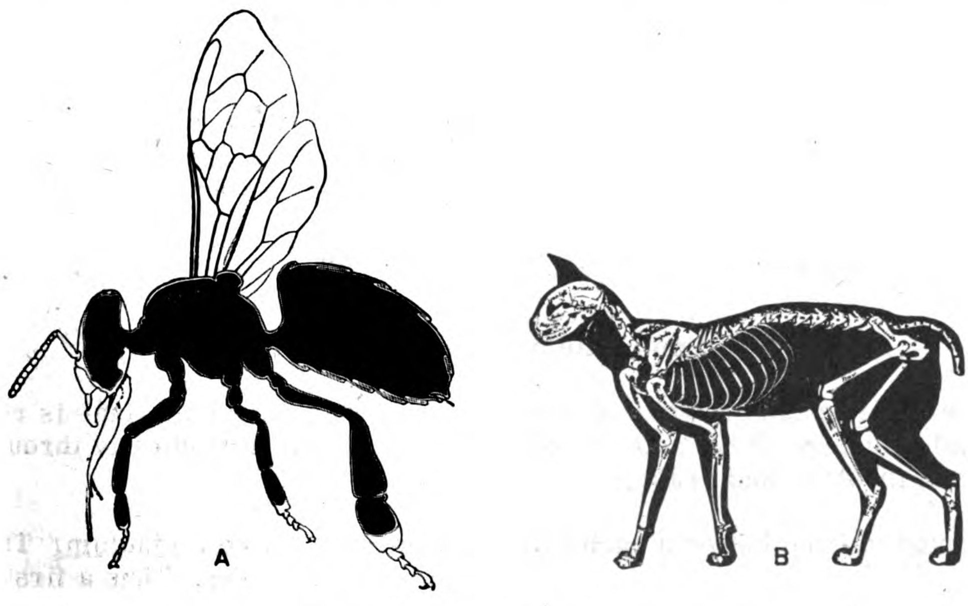


FIG. 3. A. Exoskeleton of an arthropod.
B. Endoskeleton of a mammal.

GENERAL CHARACTERISTICS OF THE ARTHROPODS

An arthropod's body is thus covered with an inexpansible shell. In order to make any considerable increase in size, this shell must be discarded and a new and larger one formed. All arthropods throw off this exoskeleton at various times during their lives, a process which is known as <u>molting.</u> Before the old shell or <u>cuticula</u> is split off, a new soft shell is secreted inside of it by the underlying layer of epidermal cells. Some of these same cells then secrete a "molting-fluid" which is poured out between the old and the new shells, loosening one from the other. The old cuticula is then split open by pressure from within and the arthropod squirms and crawls out of it, pulling its appendages free. The arthropod is now in a "soft shell" condition. In certain of the crabs, the shell remains soft for several days, during which time they are considered a delicacy because the entire claw, for example, can be eaten rather than just the inner muscles.

There is considerable expansion in the size of the arthropod while it is in the soft shell condition. This is accomplished by absorption of large quantities of water into the tissues, or by the inflation of the alimentary canal with air. Thus, when the outer portion of the cuticula begins to harden or "set", and hard, armor-like plates are formed over most of the body-wall, the new shell is of sufficient size to provide space for additional growth.

The cuticula is continuous and uninterrupted from one hard plate to another, but remains soft and flexible between the plates to permit body movement. The cuticula also extends as a thin lining over the fore- and hind-gut, but not the mid-gut.

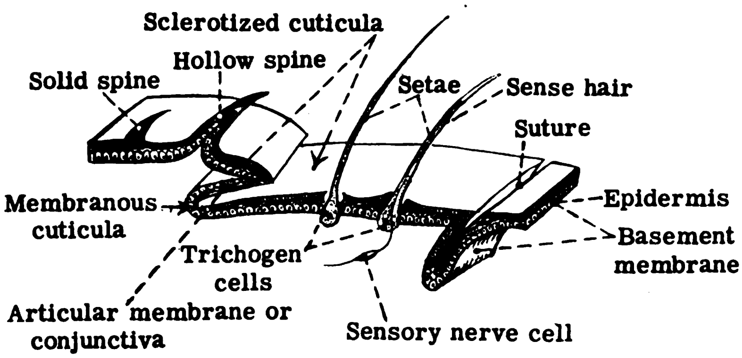


FIG. 4. Section of the body-wall of an arthropod.

In some arthropods, growth and molting cease when the adult stage is reached (as in insects), while in others growth and molting continue periodically throughout adult life (as in lobsters and crabs).

The period of time between each immature molt is called a <u>stadium.</u> The arthropod, itself, during any stadium is referred to as an <u>instar.</u> Thus a first-instar arthropod is one that has hatched from the egg, but has not yet cast its first skin. The time from hatching to the first molting is the first stadium.

GENERAL CHARACTERISTICS OF THE ARTHROPODS

The paired appendages of an arthropod are characteristically jointed, being made up of a number of rigid pieces which articulate one upon the other at connecting joints. The configuration of the joint determines the type of movement possible. Some permit movement in only one axis, as in the elbow joint of man. Others permit movement in several axes, similar to the shoulder joint of man. The jointed appendages of an arthropod are adapted for many functions such as locomotion, feeding, reception of sensation and assisting in the reproductive process. Regardless of the function of the appendage, the jointed condition is readily visible.

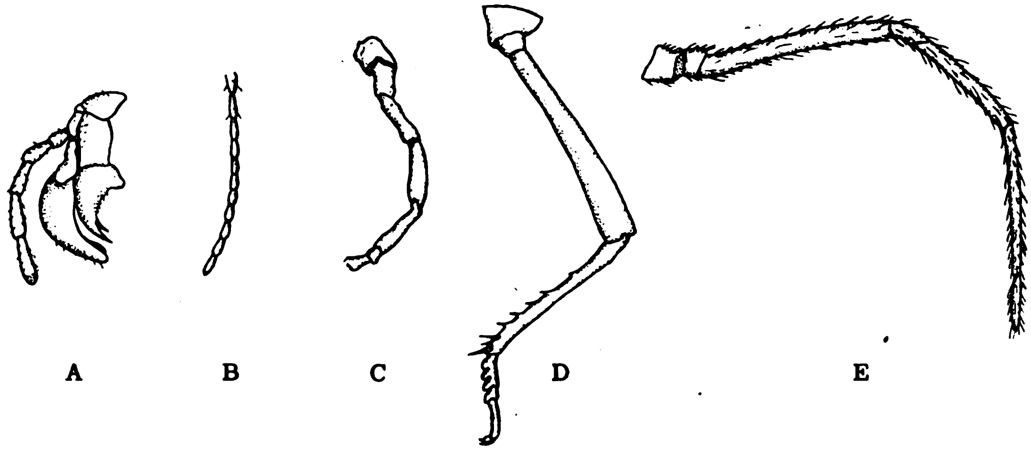


FIG. 5. Jointed appendages. A. Insect maxilla. B. Antenna. C. Leg of a tick. D. Leg of insect. E. Leg of a spider.

The arrangement of certain of the internal organ systems of arthropods is also characteristic of the phylum and helps to define the group. The nervous system consists of a dorsal brain connected to a ventral nerve cord by circumesophageal connectives. The digestive system consists of a tube running the entire length of the body, having an entrance or mouth and an exit or anus. The circulatory system is dorsal.

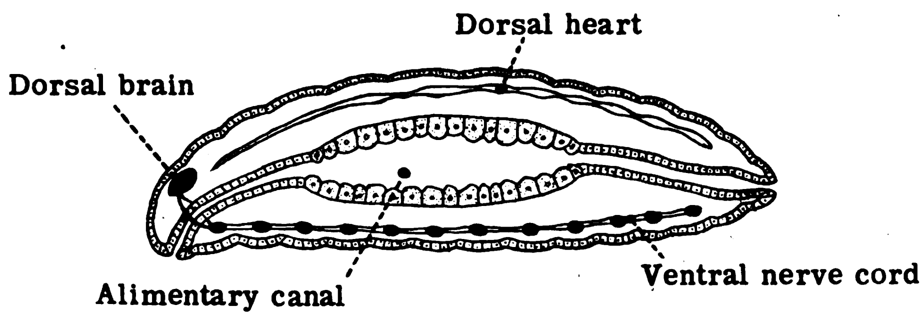
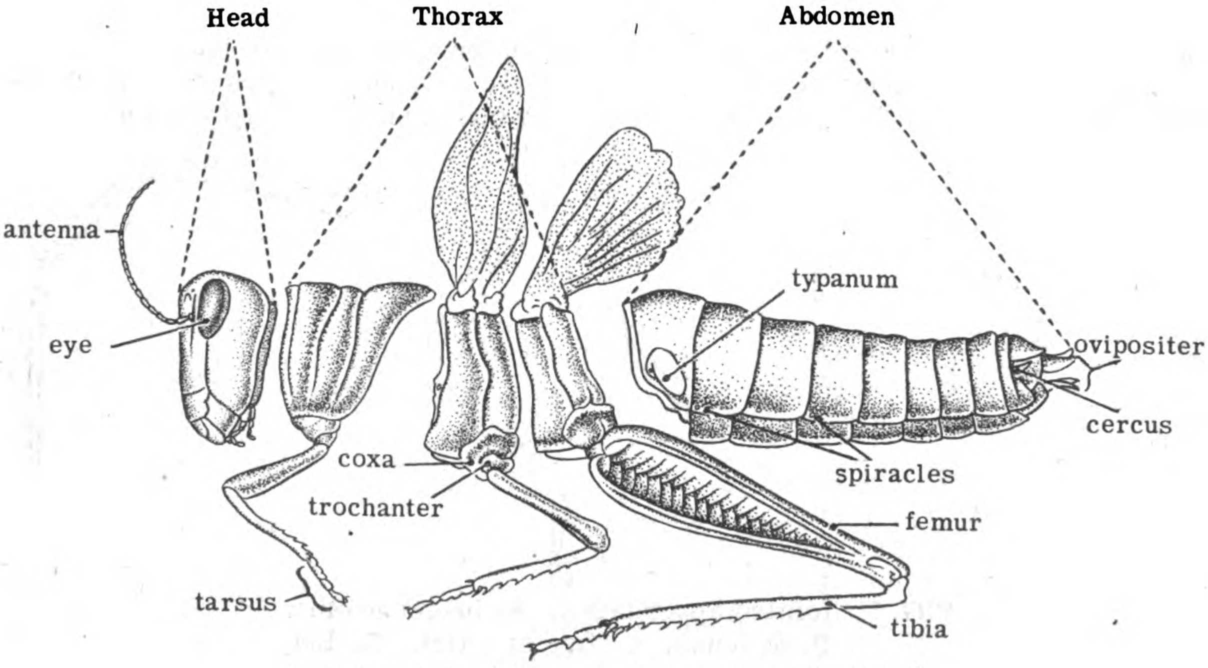


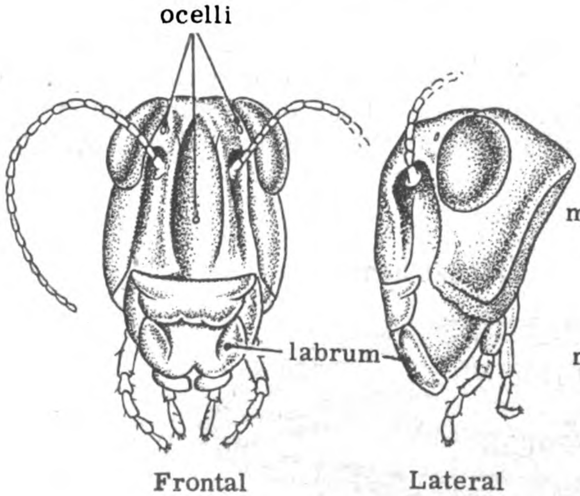
FIG. 6. Diagram of the internal systems of an arthropod.

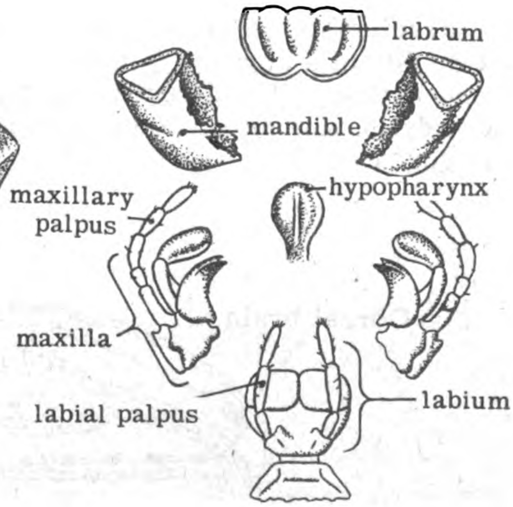
PLATE III.

THE ANATOMY OF THE GRASSHOPPER



A. Lateral view of a grasshopper (disarticulated)





B. Head

C. Mouthparts (Chewing type)

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ANATOMY OF A SELECTED ARTHROPOD -- AN INSECT

EXTERNAL ANATOMY: The grasshopper, because of its large size, illustrates well the features of the PHYLUM ARTHROPODA. The body is segmented and its parts are arranged equally along both sides of a plane dividing the body into lateral halves (bilateral symmetry); the "skin" is hard and serves as an exoskeleton; and the appendages (antennae, mouthparts, legs) are jointed.

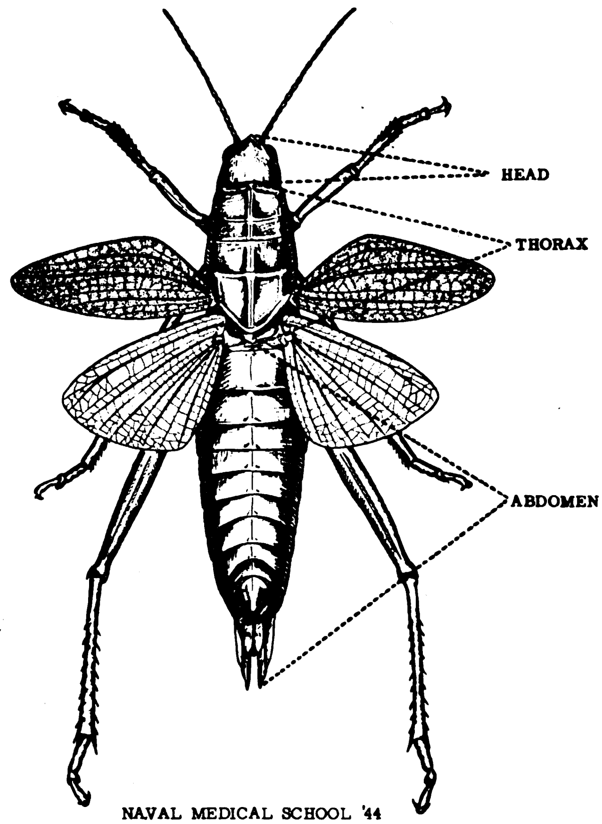


FIG. 7. Dorsal view of a grasshopper.

Further examination reveals additional features which cause the grasshopper to be included in the CLASS INSECTA. The body segments are grouped into three main regions, head, thorax, and abdomen. On the head are one pair of antennae; and on the thorax are three pairs of legs.

Conspicuous structures on the head are: (1) the two antennae, or "feelers", which are sensory in function; (2) the two large compound eyes; and (3) the chewing mouthparts.

The second body region, the thorax, is made up of three segments: prothorax, mesothorax, and metathorax. Each segment bears a pair of legs, and the last two segments each bear a pair of wings. The leg of the grasshopper (as in all insects) is made up of five regions: a basal coxa, followed by a trochanter, femur, tibia, and tarsus (foot). The two pairs of wings on a grasshopper are obviously different in

texture and shape. The front wings are leathery and serve as protective coverings for the more delicate, membranous hind pair. Insects are the only arthropods with the power of flight.

The abdomen of a grasshopper is made up of a series of segments which, except for the very last ones, are similar in shape. The last segments possess true appendages, the cerci and certain accessory reproductive structures.

INTERNAL ANATOMY: The respiratory system of a grasshopper consists essentially of a network of internal air-tubes (tracheae) which communicate with the outer air through small openings (spiracles) in the body wall and supply the individual tissue cells with air through a multiplicity of branches and microscopic tubules (tracheoles). Thus oxygen, in its gaseous state, is supplied directly to the tissues and not through the blood. Contraction and expansion of the body volume crushes or dilates the tracheae, forcing the air in and out, thus assisting in the rapid ventilation of the tracheae. In some other arthropods, gills (as in crustaceans) or "book lungs" (as in some spiders) may serve the functions of respiration in place of tracheae and tracheoles.

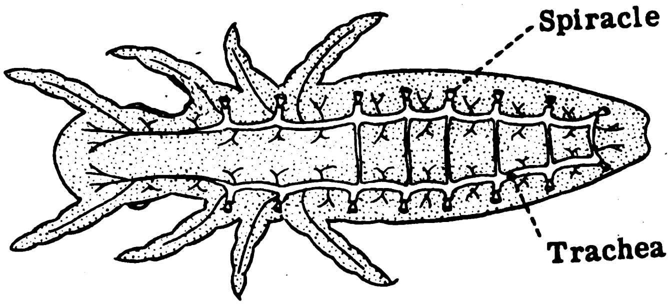


FIG. 8. Diagrammatic view of the respiratory system of an insect.

The circulatory system of a grasshopper has as its principal organ the dorsal vessel or "heart". This is a long, delicate, contractile tube, open on the anterior end, that lies just under the dorsal body-wall and extends from the posterior part of the abdomen to the head. It is so constructed that, on diastole, blood is drawn in from the surrounding body space (haemocoele) through minute valvular openings (ostia) in the side of the tube; and, on systole, this blood is squirted forward to bathe the brain and trickle down and back into the haemocoele again.

The insect's circulatory system is described as "open", because only in its brief passage through the dorsal vessel is the blood confined within the walls of a tube. The rest of the time it lies free in the haemocoele, where it bathes all the tissues, supplying them with food and removing the waste products.

Accessory structures that assist the dorsal vessel in circulating the blood are the delicate, undulating sheets of muscles called the dorsal and ventral diaphragms

and the auxilliary contractile vessels sometimes located at the bases of the legs, antennae, and wings.

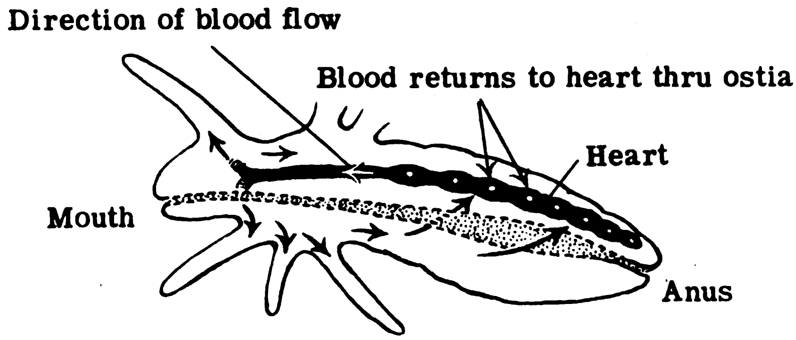


FIG. 9. Schematic drawing of the circulatory system of a grasshopper.

The blood of an insect is composed of a liquid haemolymph and nucleated haemocytes. It carries no oxygen, but transports dissolved food to the tissues and removes the waste products.

In some of the other arthropods, i.e., some of the crustaceans and arachnids, an elaborate system of blood vessels may branch out from the dorsal vessel.

The digestive system of a grasshopper is essentially a tube running the length of the body. Food is chewed as it enters the mouth. Here it is mixed with saliva from the salivary glands and is then stored in the crop, macerated to a finer state in the proventriculus, mixed with the digestive enzymes and micro-organisms from the gastric caeca, and digested by the secretions of the mid-gut, where absorption also takes place. The mid-gut is the only part of the alimentary canal that is not lined with an impermeable cuticula. The unabsorbed residue then passes back into the hind-gut, where it is joined by the metabolic wastes emptied from the malpighian tubules (which function as kidneys in insects) and passes on out through the anus.

In many arthropods, the mouth parts and the alimentary canal are greatly modified. These modifications are correlated with specialized habits.

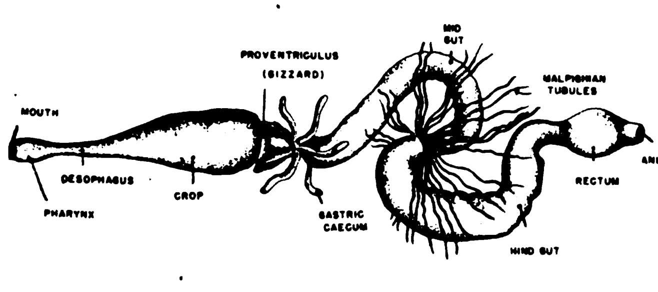


FIG. 10. Alimentary canal of a grasshopper.

ANATOMY OF AN INSECT

The central nervous system includes a complex mass, called the "brain", in the dorsal part of the head; an almost equally complex "sub-brain" on the floor of the head; and a chain of paired ventral ganglia lying beneath the alimentary canal and extending to the posterior end of the body. These nerves and certain autonomic nerves connected with the central system ennervate the various organs and muscles of the body, and associate the stimuli received from the various sensory receptors. Insects are provided with organs of varying efficiency for seeing, tasting, smelling, and hearing.

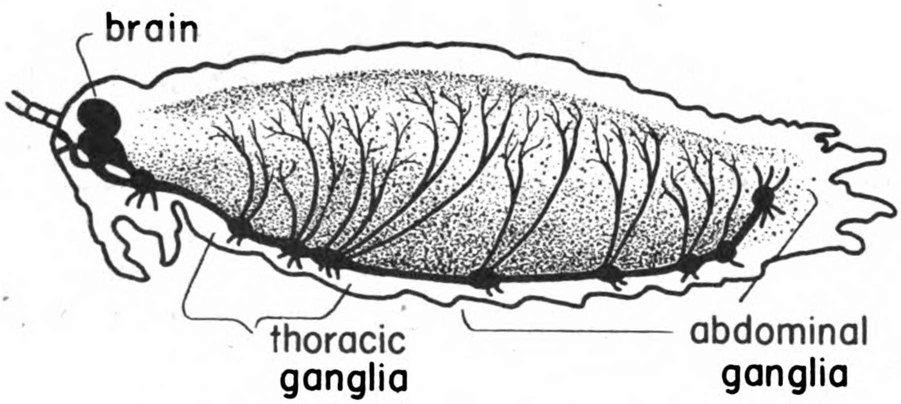


FIG. 11. Diagram of the central nervous system of a grasshopper.

The reproductive systems of male and female insects are structurally similar, but the sexes are distinct. Eggs are produced in the paired ovaries of the female and pass down the paired oviducts into a common duct, or vagina, where they are fertilized by sperm stored in accessory pouches, the spermatheca and the bursa copulatrix. This storage of sperm in the female is important because it permits the female to lay fertile eggs continuously, even though copulation may be very infrequent or occur only once.

The spermatozoa are produced in the paired testes of the male, pass down the vas deferens into the ejaculatory duct and the intromittent organ.

Both sexes have secondary sex structures attached to the terminal segments of the abdomen, these serving as claspers in the male and ovipositors in the female.

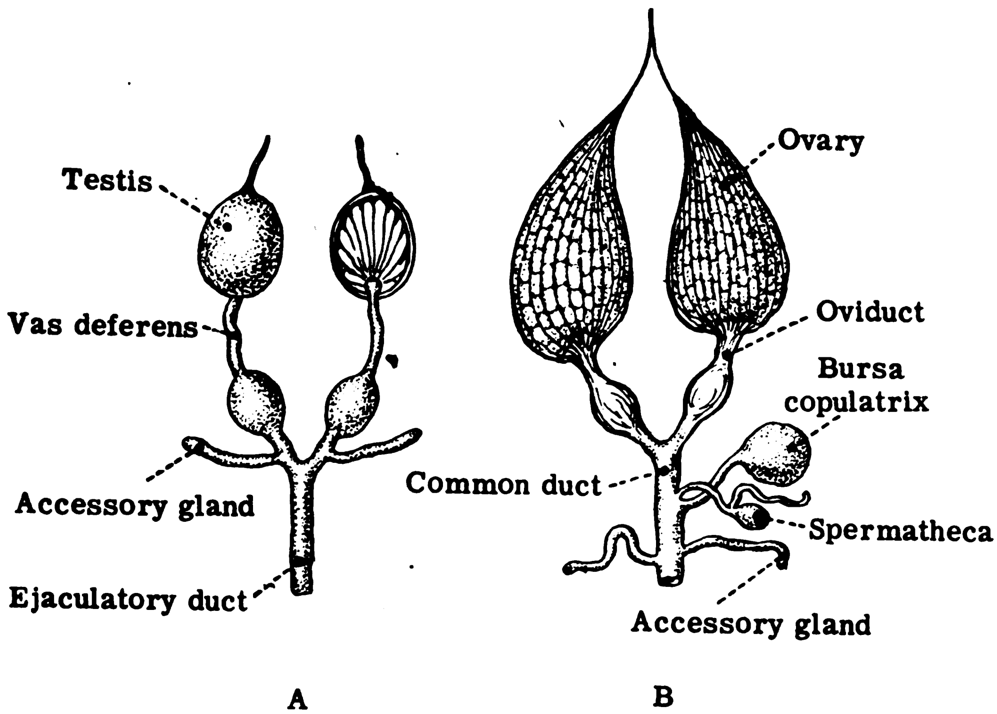


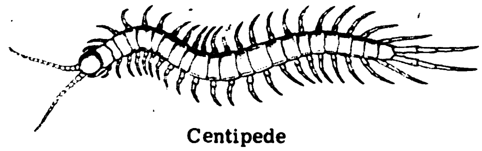
FIG. 12. Diagram of the reproductive organs of a grasshopper. A. Male. B. Female.

NOTES

PLATE IV

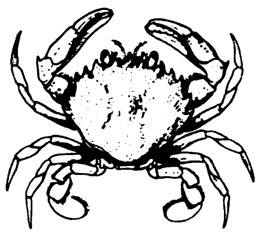
CLASSES OF ARTHROPODS

Millipede

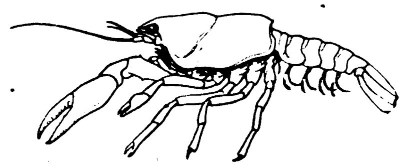


Centipede

CLASS MYRIAPODA

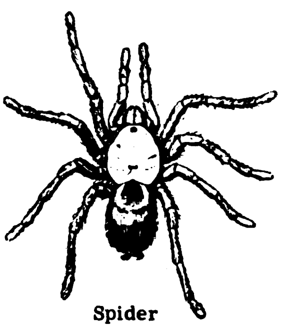


Crab

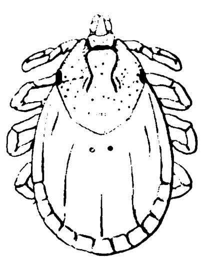


Crayfish

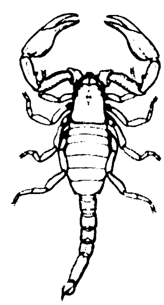
CLASS CRUSTACEA



Spider

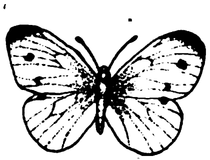


Tick

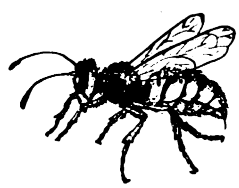


Scorpion

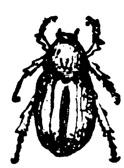
CLASS ARACHNIDA



Butterfly



Wasp



Beetle

CLASS INSECTA

NAVAL MEDICAL SCHOOL '44

SECTION II.

THE CLASSES OF MEDICALLY IMPORTANT ARTHROPODS

In the previous section, emphasis has been placed upon the structure of the arthropods. The next step is to emphasize the characters which are used to divide the arthropods of medical importance into their next smaller divisions - CLASSES.

The division of the phylum ARTHROPODA into classes is based on the grouping of the segments into body regions and on the number and arrangement of the locomotor appendages.

The various classes are graphically represented on Plate IV, and it is possible to assign a medically important arthropod to its proper class simply by comparing the specimen with the illustrations. Usually illustrations are not available for use in the identification of arthropods, especially when smaller categories (such as orders, families, genera, and species) are being considered. In the absence of illustrations, biologists use descriptive keys to aid in identification. To illustrate the foregoing, a simple descriptive key to the classes of arthropods of medical importance is given below. Opposing descriptive statements are arranged in couplets. The features of the specimen under consideration will agree with one (and only one) of the statements. At the end of the statement will be found the name of the CLASS to which the specimen belongs, or the number of another couplet from which a further choice of statements must be made. Each statement of a couplet must indicate a category of classification (in this case a CLASS) or another couplet for subsequent choice.

<u>Key to the Classes of Arthropods of Medical Importance</u>

1. Body made up of a head and a series of similar segments, each bearing one or two pairs of legs. . . . . MYRIAPODA

   Body not as above. 2

2. Body divided into three distinct regions, head, thorax, and abdomen; three pairs of legs. INSECTA

   Body not as above. 3

3. With five pairs of locomotor appendages . CRUSTACEA

   With four pairs of locomotor appendages. ARACHNIDA

THE CLASSES OF MEDICALLY IMPORTANT ARTHROPODS

Class I. MYRIAPODA

Some of the arthropods have a head region followed by a series of similar segments which comprise the trunk. Each apparent segment of the trunk bears either one or two pairs of jointed appendages. Arthropods of this type belong to the class MYRIAPODA, represented by centipedes and millipedes.

Class II. CRUSTACEA

These arthropods have the body divided into an anterior cephalothorax (head plus thorax) and an abdomen. At least five pairs of legs arise from the cephalothorax, and two pairs of antennae are present. Most of the members of this class are aquatic. Common examples are lobsters and crabs.

Class III. ARACHNIDA

In the class ARACHNIDA, four pairs of locomotor appendages are present. The body of an arachnid may be divided into two regions, as in the preceding class, or all three body regions (head, thorax, and abdomen) may be fused to form a sac-like structure. The varied nature of the arachnid body may be observed by comparing the common examples of the group (scorpion, spider, mite and tick).

Class IV. INSECTA

The largest class of the phylum is the class INSECTA or HEXAPODA. In these, the number of legs is reduced to three pairs; the body is distinctly divided into three regions - head, thorax, and abdomen; and only one pair of antennae is present. Most insects are winged.

CLASS MYRIAPODA
(centipedes and millipedes)

GENERAL CHARACTERISTICS: Myriapods have their bodies divided into two regions - a head and a trunk, the latter made up of similar segments, each bearing one or two pairs of locomotor appendages. Those bearing one pair of legs on each segment are centipedes, and those with two pairs of legs on each apparent segment are millipedes.

RELATION TO MAN: Millipedes are not venomous, since they possess no poison glands. Certain species have at times been reported from the digestive and urinary tracts of man. Others are known to be acceptable intermediate hosts of certain human tapeworms. While centipedes are apparently all provided with poison glands, the various species are not equally dangerous. The larger forms, which may reach a length up to 10 inches or more, are most likely to prove troublesome because of the greater amount of venom they secrete. It is probable that some persons, particularly small children or the very aged, may be especially sensitive to the bites of certain centipedes, but deaths have rarely been attributed to their bites.

LIFE-CYCLE AND HABITS: Since these forms are rarely of any great importance, no detailed discussion of life cycle and control is offered. Both millipedes and centipedes usually live in moist, protected places and are largely nocturnal in habit. During the day, they may be found under loose bark of dead trees or under logs, boards, stones, leaves and other debris on the ground. In handling such material, there may be some chance of accidentally grasping a centipede where these forms are commonly found.

CONTROL: No control measures, other than avoidance, are usually necessary.

CLASS CRUSTACEA
(crabs, lobsters, crayfish, copepods)

GENERAL CHARACTERISTICS: Crustaceans are aquatic arthropods which breathe by means of gills. They have two pairs of antennae and at least five pairs of legs. The larger familiar forms, such as the crabs, crayfish, and lobsters, have a calcareous, tough exoskeleton, while the less known microcrustaceans are more delicate in structure.

RELATION TO MAN: A number of the microcrustaceans serve as intermediate hosts of the tapeworms, flukes, and nematodes, some of which are important parasites of man.

Cyclops and *Diaptomus* play a role in the life cycle of the fish tapeworm of man (*Diphyllobothrium latum*). These forms act as the first intermediate host in the parasite's life cycle, fish becoming infected by eating infected microcrustacea; man, in turn, by eating raw infected fish.

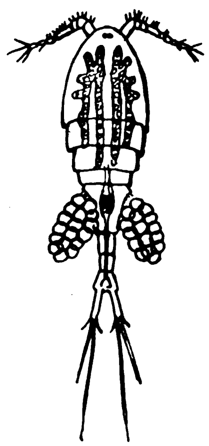


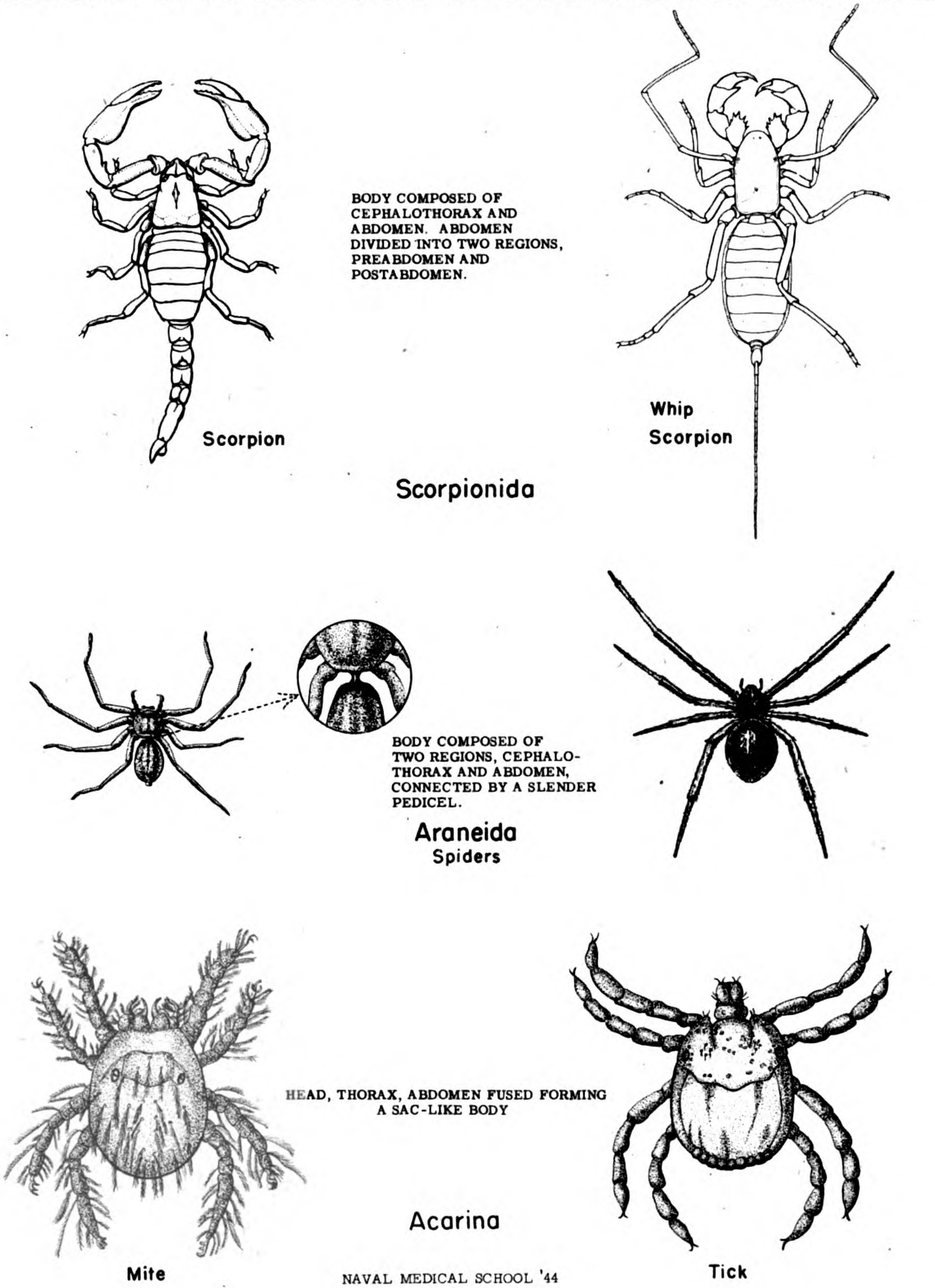
FIG. 13. *Cyclops*.

The Guinea worm (*Dracunculus medinensis*) passes its intermediate stage in the minute crustacean, *Cyclops*, the infection passing to man when he ingests infected *Cyclops* in drinking water. The larger crustaceans, crabs, lobsters and crayfish, may also harbor intermediate stages of parasites. The important lung-fluke, *Paragonimus westermani*, has as its intermediate host various species of crayfish and fresh-water crabs.

CONTROL: Control consists of insistence on a safe water supply in case of the Guinea worm, and of thorough cooking of fish and shell-fish in the case of the fish tapeworm and the lung-fluke.

PLATE V.

PRINCIPAL CHARACTERS FOR IDENTIFYING ORDERS OF ARACHNIDS OF MEDICAL IMPORTANCE



THE CLASSES OF MEDICALLY IMPORTANT ARTHROPODS

CLASS ARACHNIDA
(spiders, scorpions, mites, ticks)

GENERAL CHARACTERISTICS: The arachnids are air-breathing arthropods in which at least the first two body regions (head and thorax) are fused to form a cephalothorax. There are four pairs of legs and no antennae.

RELATION TO MAN: Two orders of arachnids, the ARANEIDA (spiders) and the SCORPIONIDA (scorpions), are of some importance because of their venomous bites or stings. The third order, the ACARINA, includes the mites and ticks. These are of far greater importance because they are concerned in the transmission of such serious diseases as Rocky Mountain spotted fever and tsutsugamushi. All three classes are discussed more fully below.

Key to the Orders of Arachnids of Medical Importance

1. Body divided into two regions, cephalothorax and abdomen. 2

   Body with one region formed by fusion of head, thorax, and abdomen. . . . . ACARINA

2. Abdomen joined to cephalothorax by a narrow pedicel. Segmentation absent or indistinct. . . . . ARANEIDA

   Abdomen broadly joined to cephalothorax. Body distinctly segmented. . . . . SCORPIONIDA

ORDER SCORPIONIDA
(scorpions)

GENERAL CHARACTERISTICS: The scorpions are arachnids characterized by the possession of a pair of stout appendages bearing pincer-like claws and situated just in front of the four pairs of walking legs. The terminal portion of the abdomen is much narrowed and is tipped with a ventrally-curved poison spine. The poison is produced in glands in the last segment and in some of the larger scorpions seems to resemble cobra venom in its action.

RELATION TO MAN: The sting of some of the larger, more venomous, tropical forms may cause death, especially in very young children or in aged persons. The effects of the sting are burning pain, nausea, and profuse sweating. In infants and children, convulsions are common, and it is in these individuals that death may occur.

LIFE CYCLE AND HABITS: Scorpions are nocturnal and are predatory on insects and other small forms. During the day, they are to be found in protected places, hiding under stones, logs, boards, debris, the bark of dead trees or in fire wood, shoes, or folds of clothing. When they are disturbed or accidentally touched in such situations, there is danger of being stung with very painful results.

CLASS ARACHNIDA

ORDER ARANEIDA
(spiders)

GENERAL CHARACTERISTICS: A spider can be recognized by its peculiar body organization. It is divided into two regions, cephalothorax and abdomen, which are joined together by a slender pedicel or stalk. The cephalothorax bears the mouth parts and the legs. The abdomen is rounded, soft, and externally unsegmented.

RELATION TO MAN: Most spiders are harmless individuals which pay little or no attention to man. Occasionally man blunders into the homes of spiders and provokes an attack. Some spiders have poisonous substances in their body fluids or in special glands. These poisonous substances introduced into the human body may cause serious reactions. Latrodectus mactans, the black widow spider, is a well known poisonous species occurring in many parts of the western hemisphere.

LIFE-CYCLE AND HABITS: The gravid female deposits her eggs in a woven cup of silk, and when oviposition is complete the entire cup is enclosed in a tough, water-tight silken covering. The spiderlings which hatch from the eggs make holes in the tightly woven envelope and escape. After several molts (7 or 8), the adult stage is attained.

Spiders suck up the body juices and predigested solid tissues of insects and other arthropods. Many of these are captured when they come in contact with the web which serves as a trapping device. Once the prey is enmeshed in the web, the spider administers a lethal bite and then digests and sucks the body contents at its leisure.

CONTROL: Collection and destruction of egg sacs and webs.

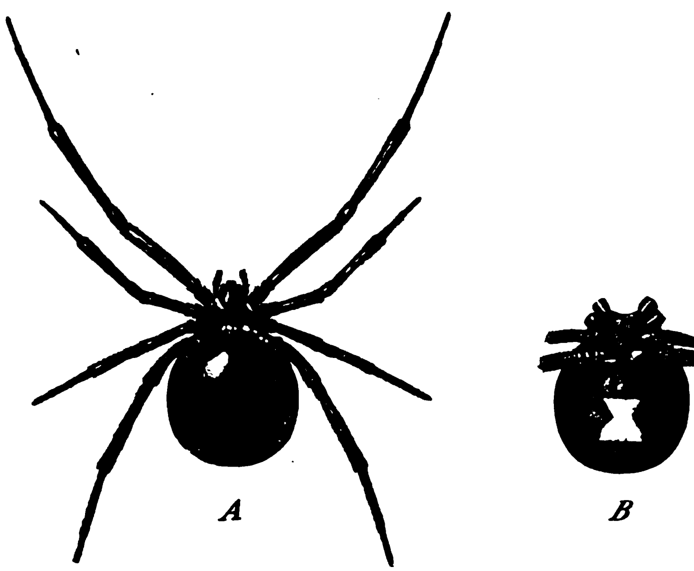


FIG. 14. A. Female black widow spider, dorsal view.
B. Ventral view of abdomen showing the "hour glass".

CLASS ARACHNIDA

ORDER ACARINA
(ticks and mites)

GENERAL CHARACTERISTICS: The majority of the acarids are round or oval forms with the head, thorax, and abdomen fused to form a single region. The anterior portion of the body is modified to form a capitulum, made up of a central hypostome and paired chelicerae and palpi, which functions in attachment and food-getting. Four pairs of legs are present in the adults.

The order ACARINA includes two groups of organisms, the ticks and the mites. Mites are usually small forms in which the hypostome is hidden and unarmed, while ticks are larger forms in which the hypostome is exposed and armed with teeth or hooks. In a sense, ticks are merely one superfamily of very large mites, but for convenience the ticks and mites will be considered separately. They may be differentiated as follows:

Mites	Ticks
1. Body clothed with long hairs.	1. Body clothed with short hairs or lacking.
2. Hypostome hidden and unarmed.	2. Hypostome exposed and possessing teeth.
3. Usually small size, many microscopic.	3. Larger size, all macroscopic.
4. Body texture membranous in appearance.	4. Body texture leathery in appearance.
5. Pedipalps almost lacking in segmentation in some forms.	5. Pedipalps prominent and distinctly segmented.
6. Chelicerae reduced to blades or rods.	6. Chelicerae heavily chitinized bearing strong cutting teeth at their distal end.

TICKS

RELATION TO MAN: All ticks are parasitic during some period of their lives. They are annoying pests and in addition they are transmitters of the causative agents of many diseases. In three regions of the world, South Africa, Australia, and Northwestern United States, there occurs in man and in certain domestic animals a condition known as tick paralysis. The exact etiology of this condition still remains undetermined, but the prevailing opinion is that a substance secreted by the tick is responsible for the paralysis. The importance of ticks as transmitters of disease agents long has been recognized. Among the more important diseases associated with ticks are Rocky Mountain spotted fever, Sao Paulo fever, relapsing fever, and tularemia. For a complete list, see the summaries at the end of the manual.

TICKS

LIFE-CYCLE AND HABITS: There are four stages in the development of a tick: egg, larva, nymph, and adult.

Egg: The eggs are laid on the ground, in the cracks and crevices of houses, or in the nests and burrows of animals. They may be laid in one large batch, or in several smaller lots. The period of incubation varies from two weeks to several months.

Larva: This is the stage which issues from the egg. It is a small form and has only six legs. Usually, the larva requires at least one feed of blood before it can develop to the next stage.

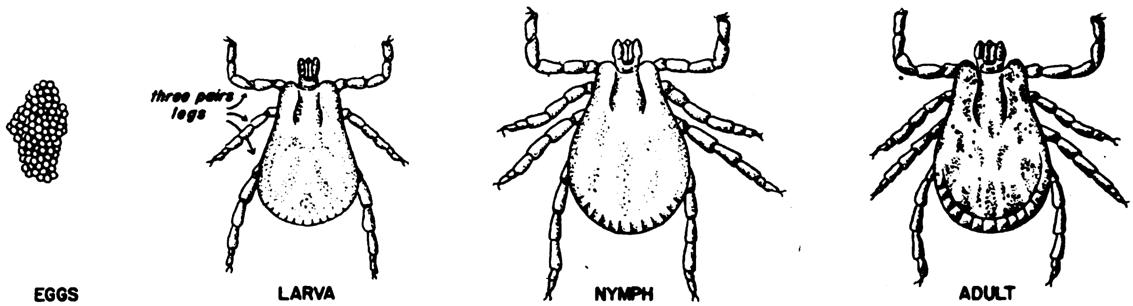


FIG. 15. Developmental stages of a tick.

Nymph: This is an eight-legged form which results from the molting of the mature larva. A nymph is sexually immature and lacks a genital opening. All nymphs require one or more blood meals before transforming to the adult.

Adult: Some adult ticks require a blood meal before copulation; others do not. Adult female ticks feed once, or several times, before oviposition.

Ticks are usually regarded as blood-sucking ectoparasites of vertebrates, although it is worth pointing out that many of them do not remain on the host after the blood-sucking act is completed and are, strictly speaking, free-living organisms during the periods when they molt and lay eggs. There are two families of ticks, the IXODIDAE, or hard ticks, and the ARGASIDAE, or soft ticks; and, since their habits vary, they will be considered separately.

The hard ticks are so-called because they possess a hard back -- shield or scutum. This covers the entire dorsal surface of the male, but extends over only a small part of the anterior dorsum of the female. These ticks attach themselves firmly to their hosts during the blood-sucking act and may remain upon them for days, or even weeks, before engorgement is completed. The larvae and nymphs take only one blood meal each, and the adult female takes only a single enormous blood meal before dropping off the host to digest the blood and lay a single large batch of eggs. Most hard ticks have either two or three hosts during their development, although one or two species have only a single host.

The soft ticks are so-called because they lack the rigid scutum. They have much the same habits as bedbugs, hiding in cracks and crevices in houses, or in the nests of their hosts, and coming out at night to feed on the blood of the host for a short period, usually less than half an hour. The larvae and nymphs usually feed several times before molting. The adult female feeds a number of times, laying a small batch of eggs after each feed. Soft ticks have many hosts. This increases their potentialities as vectors of disease organisms. Both sexes of soft ticks are similar externally.

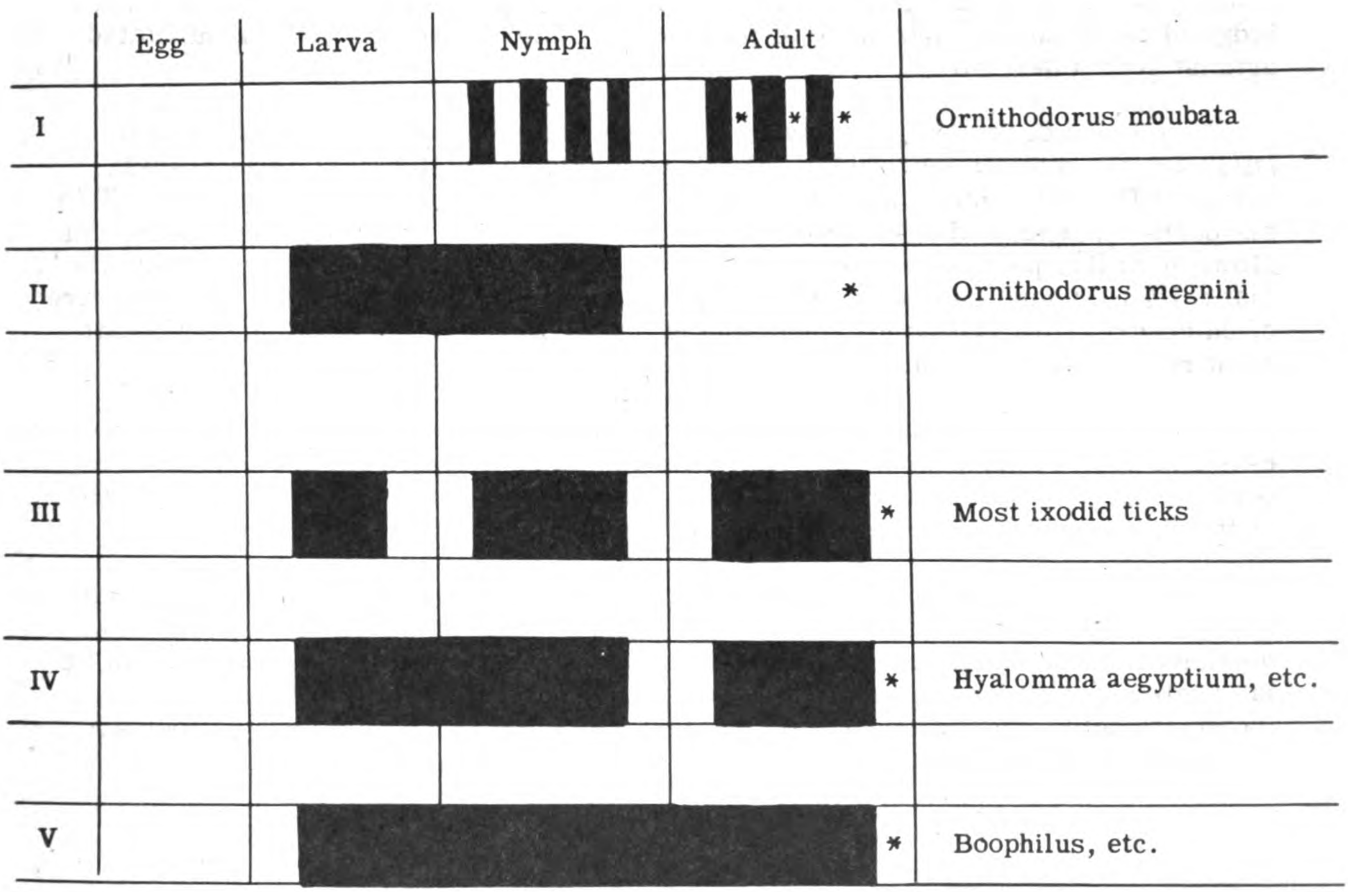


FIG. 16. Diagram illustrating the different types of life cycles of various ticks. Black areas indicate periods of attachment to host; asterisks indicate ovipositions.

CONTROL: Methods of control vary with the species of tick in question. For soft ticks, control measures are directed at the homes of the host animals. If the soft ticks are in buildings, methods similar to those used against bedbugs are effective. Control of these soft ticks living in the burrows of wild rodents is almost impossible. The control of hard ticks is relatively simple in the case of those that have but a single host. The cattle tick of our Southern States is effectively controlled by dipping the stock in arsenical solutions or by a system of pasture rotation. The control of two- and three-host ticks has been discouraging. In the case of the Rocky Mountain spotted fever tick, definite local good has been accomplished by dipping, grazing control, and the control of rodents; but lack of permanent results and knowledge of the relative importance of the various factors involved have all militated against substantial gains.

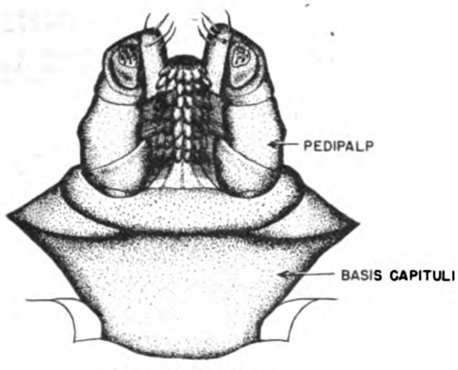
Ticks on dogs, and probably on other host animals, can be controlled with DDT, a new synthetic insecticide. It can be applied as a 10% dust or as a wash, using a DDT emulsion. Emulsions can be prepared by dissolving five parts DDT in six parts benzene, adding one part of an emulsifier (such as Dreft) and pouring this slowly into five parts of rapidly stirred water. Preliminary experiments indicate that a 1% DDT dust can be used to kill ticks on vegetation. Roadsides and paths are often congregating places for ticks, and in heavily infested camp areas such treatment may prove practical.

The new GI repellent is highly effective against larval ticks and moderately effective against nymphal ticks. Results against adult ticks have not been so successful, but some protection is obtained. The repellent can be sprayed at the rate of three to four ounces to the entire outer garment.

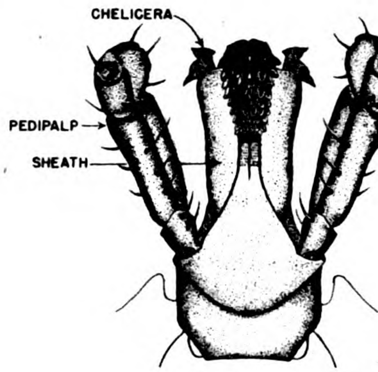
For individual protection against tick bites, one should wear high shoes and the lower ends of the trouser legs should be secured in some way to prevent tick entrance. Ticks should be removed as soon as they are discovered and this can be facilitated by rubbing the tick with kerosene, oil, or vaseline, which causes it to loosen its hold. The bite should be treated with some antiseptic, such as iodine.

TICKS

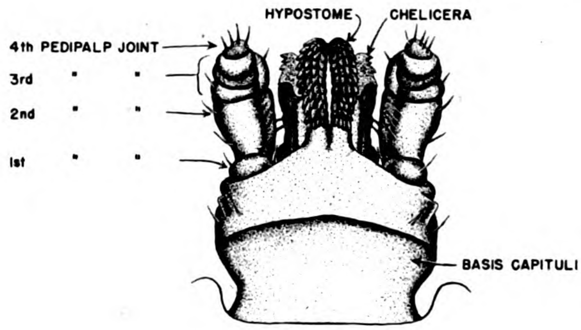
SPECIAL FEATURES OF TICK ANATOMY: The structure of the capitulum of a hard tick is quite complicated. An illustration is provided to aid the student in the identification of the parts.



Hexagonal Capitulum
Of RHIPICEPHALUS



Rectangular Capitulum
With Elongated Pedi-
palps Of AMBLYOMMA



Rectangular Capitulum
Of DERMACENTOR

FIG. 17. Capitula of three genera of ticks.

Classification of Ticks of Medical Importance

Mouth parts situated ventral to the anterior extremity, not visible in dorsal aspect; scutum absent. . . . . ARGASIDAE

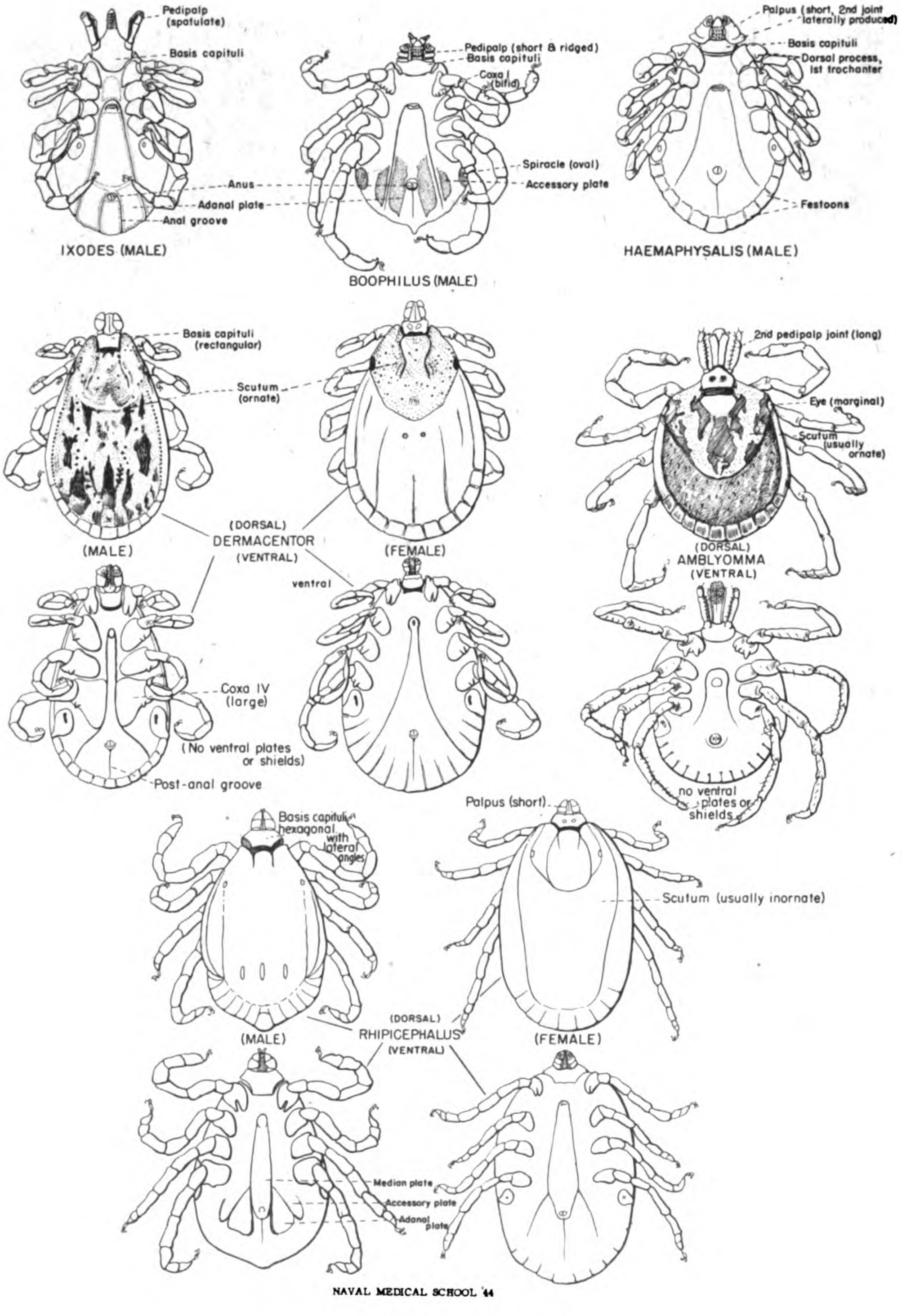
Mouth parts situated forward and beyond the anterior border, visible in dorsal aspect; scutum present. . IXODIDAE

FAMILY IXODIDAE

This family contains ticks which have a scutum and hence are known as "hard" ticks. The capitulum projects at the anterior extremity, so that the mouth parts can be seen from above. There are only ten important genera and probably some three hundred species known.

PLATE VI.

GENERIC CHARACTERS OF FAMILY IXODIDAE (Hard Ticks)



NAVAL MEDICAL SCHOOL '44

SPECIAL FEATURES OF TICK ANATOMY: The structure of the capitulum of a hard tick is quite complicated. An illustration is provided to aid the student in the identification of the parts.

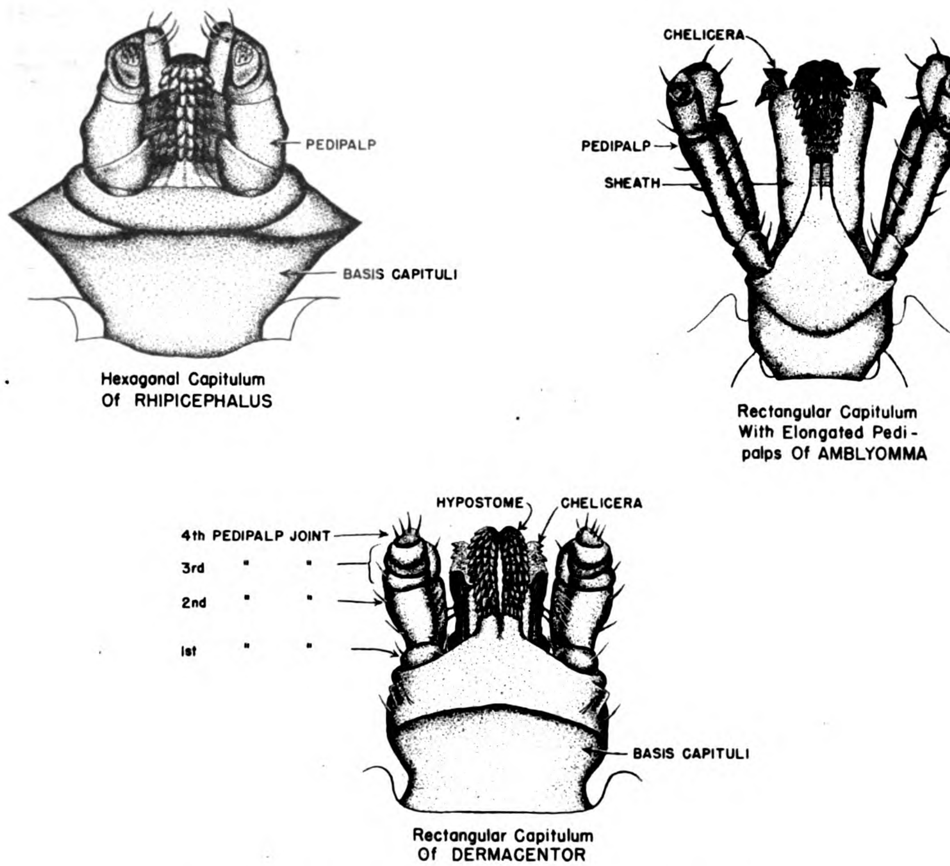


FIG. 17. Capitula of three genera of ticks.

Classification of Ticks of Medical Importance

Mouth parts situated ventral to the anterior extremity, not visible in dorsal aspect; scutum absent. . . . . ARGASIDAE

Mouth parts situated forward and beyond the anterior border, visible in dorsal aspect; scutum present. . IXODIDAE

FAMILY IXODIDAE

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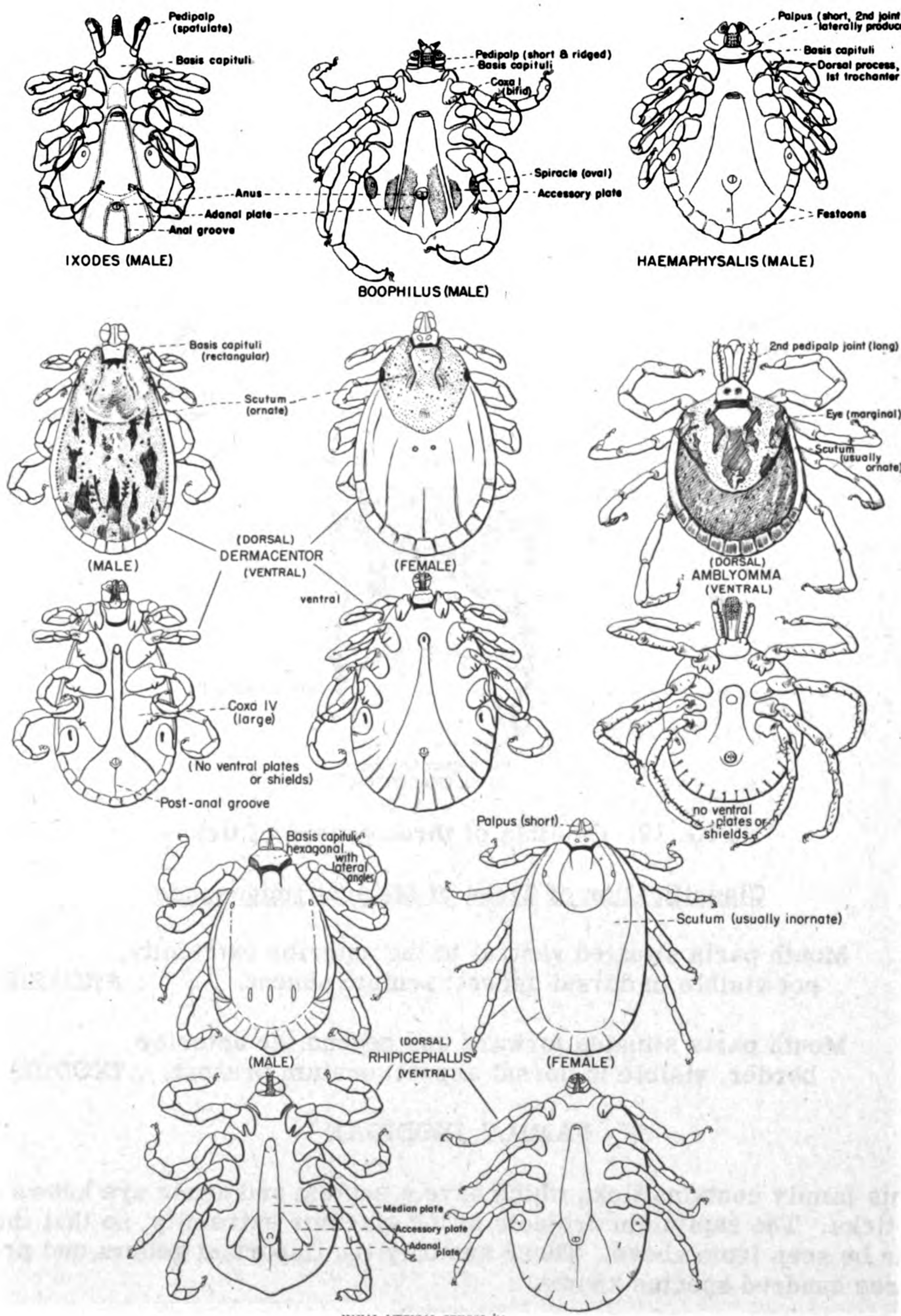
GENERIC CHARACTERS OF FAMILY IXODIDAE (Hard Ticks)



NAVAL MEDICAL SCHOOL '44

TICKS

Keys to the Principal Genera of Ixodidae

1. Anal groove running in front of anus; pedipalps usually spatulate in form; male with numerous ventral plates. . . . . <u>Ixodes</u>

   Anal groove either running behind anus or so indistinct that it cannot be seen clearly. 2

2. Mouth parts about as long as basis capituli; second joint of pedipalps not much longer than wide. 3

   Mouth parts much longer than basis capituli; second joint of pedipalps much longer than wide. 8

3. Anal groove plainly visible; festoons usually present. 4

   Anal groove absent or indistinct; festoons absent. 7

4. Second joint of pedipalps laterally produced, so that it extends beyond the edges of the basis capituli; eyes absent. . . . . . <u>Haemaphysalis</u>

   Second joint of pedipalps not laterally produced; eyes present 5

5. Basis capituli rectangular in dorsal view; scutum usually ornate; male without ventral plates; fourth coxa of male much larger than the others. . . . . <u>Dermacentor</u>

   Basis capituli hexagonal in dorsal view; scutum usually not ornate. 6

6. Male without ventral plates and with fourth coxa much larger than the others. . . . . <u>Rhipicentor</u>

   Male with ventral plates and with fourth coxa not much larger than the others. . . . . <u>Rhipicephalus</u>

7. Male with forked pre-anal plate; joints of fourth pair of legs greatly swollen. . . . . <u>Margaropus</u>

   Male with paired adanal and accessory plates; joints of fourth pair of legs normal. . . . . <u>Boophilus</u>

8. Eyes absent; males without ventral plates. . . . . <u>Aponomma</u>

   Eyes present. 9

9. Eyes submarginal; males with ventral plates. . . . . <u>Hyalomma</u>

   Eyes marginal; males without ventral plates. . . . . <u>Amblyomma</u>

TICKS

FAMILY ARGASIDAE

This family contains those ticks which lack a scutum and hence have been called "soft" ticks. There is very little sexual dimorphism, the males closely resembling the females. The adults, even when engorged, never increase much in size, and, when flattened from fasting, they resemble bedbugs. There are only two genera, Argas and Ornithodorus.

Key to the Genera of Argasidae

1. Capitulum entirely invisible dorsally, in adults distant by about its own length from the anterior border. On both dorsum and venter, numerous symmetrically arranged discs, generally oval or round, more or less disposed in radial lines. Body flattened, oval or rounded, with a distinct flattened margin which gives the body a sharp edge. . . . . Argas

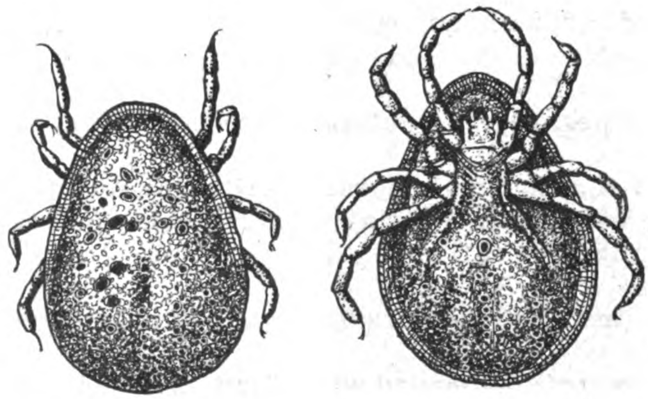


FIG. 18. Dorsal and ventral views of Argas.

2. Capitulum sub-terminal, its anterior portions often visible dorsally in the adult. Discs present or absent; but when present, not arranged radially. Body margin thick and not clearly defined. . . . . Ornithodorus

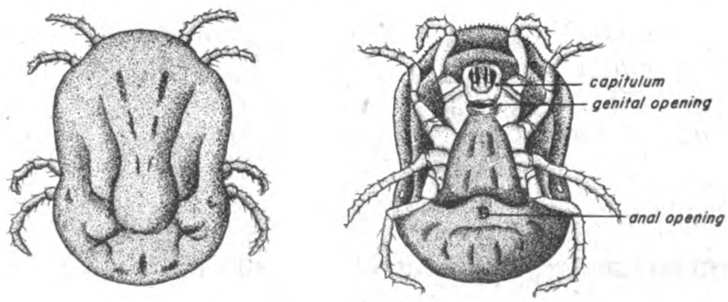


FIG. 19. Dorsal and ventral views of Ornithodorus.

TICKS

Keys to the Principal Genera of Ixodidae

1. Anal groove running in front of anus; pedipalps usually spatulate in form; male with numerous ventral plates. . . . . <u>Ixodes</u>

   Anal groove either running behind anus or so indistinct that it cannot be seen clearly. 2

2. Mouth parts about as long as basis capituli; second joint of pedipalps not much longer than wide. 3

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4. Second joint of pedipalps laterally produced, so that it extends beyond the edges of the basis capituli; eyes absent. . . . . . <u>Haemaphysalis</u>

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5. Basis capituli rectangular in dorsal view; scutum usually ornate; male without ventral plates; fourth coxa of male much larger than the others. . . . . <u>Dermacentor</u>

   Basis capituli hexagonal in dorsal view; scutum usually not ornate. 6

6. Male without ventral plates and with fourth coxa much larger than the others. . . . . <u>Rhipicentor</u>

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8. Eyes absent; males without ventral plates. . . . . <u>Aponomma</u>

   Eyes present. 9

9. Eyes submarginal; males with ventral plates. . . . . <u>Hyalomma</u>

   Eyes marginal; males without ventral plates. . . . . <u>Amblyomma</u>

FAMILY ARGASIDAE

This family contains those ticks which lack a scutum and hence have been called "soft" ticks. There is very little sexual dimorphism, the males closely resembling the females. The adults, even when engorged, never increase much in size, and, when flattened from fasting, they resemble bedbugs. There are only two genera, Argas and Ornithodorus.

Key to the Genera of Argasidae

1. Capitulum entirely invisible dorsally, in adults distant by about its own length from the anterior border. On both dorsum and venter, numerous symmetrically arranged discs, generally oval or round, more or less disposed in radial lines. Body flattened, oval or rounded, with a distinct flattened margin which gives the body a sharp edge. . . . . Argas

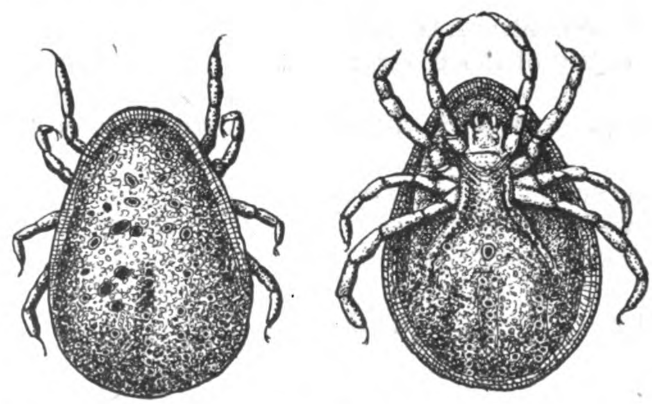


FIG. 18. Dorsal and ventral views of Argas.

2. Capitulum sub-terminal, its anterior portions often visible dorsally in the adult. Discs present or absent; but when present, not arranged radially. Body margin thick and not clearly defined. . . . . Ornithodorus

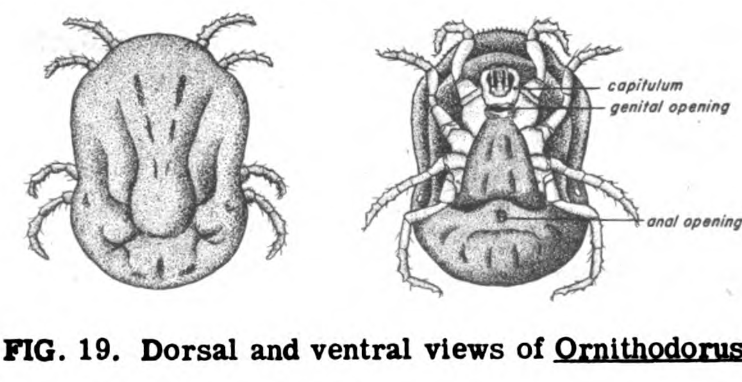


FIG. 19. Dorsal and ventral views of Ornithodorus.

ORDER ACARINA

MITES

RELATION TO MAN: The mites as a group are free-living. Only a few members are parasitic. Some of the parasitic forms are the cause of mange and scabies of man and animals. The larval stages of certain other mites of the family TROMBIDIIDAE are transmitters of an important rickettsial infection of man, variously known as tsutsugamushi, Japanese river fever, or scrub typhus. The tropical rat mite, Liponyssus bacoti, has been implicated in the spread of endemic typhus to man. It is also an important cause of a rather severe dermatitis. Certain other mites, normally feeding on detritus, may occasionally cause a temporary dermatitis in man. Parasitic mites of other animals may also attach themselves to man, causing a temporary skin irritation.

LIFE CYCLE AND HABITS: As in the ticks, mites have four stages in their development - egg, larva, nymph, and adult. Nearly all species lay eggs, although there are a few which retain the eggs within the body until hatched, a phenomenon known as ovoviviparity. From the egg, there emerges a six-legged larva which usually soon molts and becomes an eight-legged nymph. After a short time the nymph, in turn, molts and the fully developed adult appears. The life cycle of many species is completed in less than four weeks; in some it is as short as eight days.

Although there are several families of mites which contain species annoying to man, only two, the SARCOPTIDAE (itch mites) and the TROMBIDIIDAE (red bugs), will be considered here.

FAMILY SARCOPTIDAE
(itch mites)

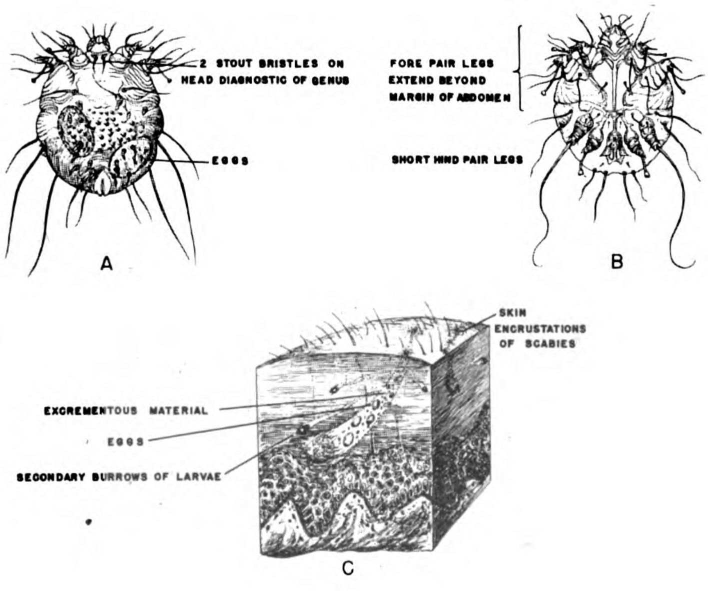


FIG. 20. Sarcoptes scabiei. A. Dorsal view. B. Ventral view. C. Burrows in the skin.

MITES

In the SARCOPTIDAE, the impregnated females (about 0.4 mm. long) excavate tortuous tunnels in the epidermis, especially between the fingers and toes, on the groin and external genitals, and in the armpits where the skin is thin and delicate. The tunnels contain the egg-bearing female at the blind end; scattered along behind are feces, eggs, larvae, and nymphs.

Scabies is acquired by contact with infested persons or clothing, the gravid females transferring to uninfested hosts. Scabies is a very important military disease. In the last war, especially, it accounted for a large number of lost man-hours..

CONTROL: The control of scabies consists in thorough and prompt treatment of infested individuals to prevent the spread of mites to others. A new development in scabies control is the use of one part of the following emulsion concentrate diluted in five parts of water.

Benzyl benzoate.	68 per cent by weight
Ethyl p-aminobenzoate (benzocaine)	12 per cent by weight
DDT.	6 per cent by weight
"Tween-80" (or other emulsifier) .	14 per cent by weight

The benzyl benzoate serves both as a solvent for the DDT and as a scabicide. The DDT is the main scabicide and the ethyl p-aminobenzoate is an ovicide. The ethyl p-aminobenzoate and DDT are dissolved in the benzyl benzoate in the stated proportions. Moderate heat may be applied to increase the rate of solution. After the concentrate is diluted in water, it should be applied by spray or sponge to the entire body, paying particular attention to the infested areas. Approximately 50 cc. of the solution will be required for such a treatment. The material should be allowed to remain on the body for at least 12 hours. Application should be repeated after a week, if necessary. The same formula can be used as a liquid preparation for the control of body, head, and crab lice. Modifications of the above or new formulae may be available with additional research on the control of these parasites.

Another treatment often used is as follows: The patient's body is first thoroughly scrubbed with green soap and soaked in warm water. The entire body is then rubbed with an ointment and left overnight. The ointment consists of a five per cent suspension of flowers of sulfur in lanolin, or one part pyrethrins (0.75%), two parts lanolin, and one part vaseline. Treatment should be repeated in 6-10 days to kill the newly hatched larvae, care being taken not to reinfest the patient with infested clothing.

MITES

FAMILY TROMBIDIIDAE
(chiggers)

The "red bugs", "chiggers", or "harvest mites" are the parasitic larvae of large soil-inhabiting mites of the family TROMBIDIIDAE, the nymphs and adults of which are non-parasitic and live only as scavengers on decaying vegetation. The chiggers attach themselves to the skin, usually close to a hair, and inject an irritating secretion which continues to cause a severe itching for several days after they have dropped off or have been removed. Chiggers do not burrow into the skin as do the sarcoptid mites.

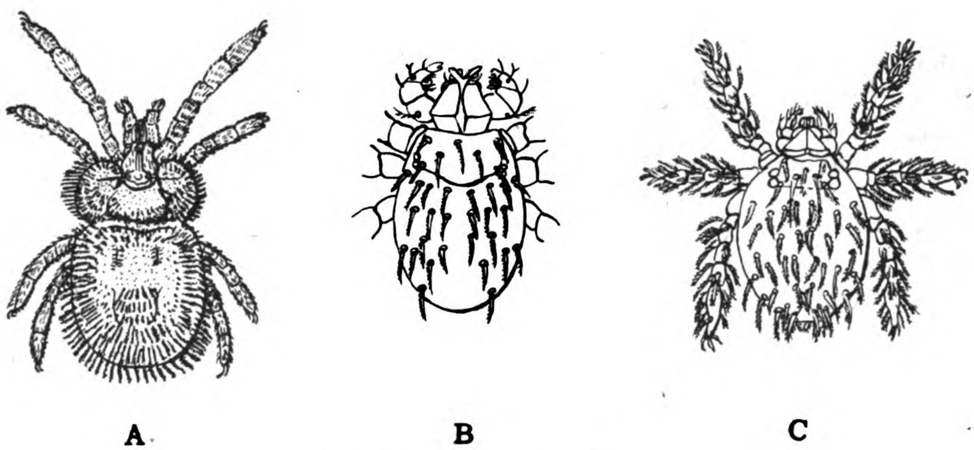


FIG. 21. Chiggers or red bugs.
A. _Trombicula alfreddugesi_ adult
B. _Trombicula alfreddugesi_ larva
C. _Trombicula akamushi_ larva

Tsutsugamushi is one of the most important mite-borne diseases. The disease occurs in the New Guinea-Bougainville area, the Dutch East Indies, Australia, Philippines, Malay States, India, Formosa, Korea, and Japan. It is a _rickettsial_ infection transmitted by larval trombiculid mites. _Trombicula akamushi_, the kedani mite, is the important vector in Japan, Malay, and Sumatra. _Trombicula delhiensis_ and _T. schuffneri_ have also been incriminated in Malay and Sumatra, and other species of _Trombicula_ may also be involved. These larval mites are hairy, orange-red forms, scarcely visible to the naked eye, about 400 x 200 microns in size.

Various field rodents, including rats and mice, are the natural hosts for the larval mites. They may also serve as the natural reservoir of the tsutsugamushi rickettsia, although evidence for this is not conclusive. When the parasitic _larval_ mites feed on an infected host, they pick up the infection and retain it through their free-living nymphal and adult lives, during which time they are vegetable feeders only. The infection is passed on to the next generation through their eggs. It is these resultant second generation _larval_ mites which bite man and transmit the disease.

MITES

In tsutsugamushi areas, these mites are most abundant in jungle grass, brush, and uncultivated areas where they are sometimes locally concentrated. Troops setting up camp areas in kunai grass or in adjacent jungle are most likely to become mite-infested and develop tsutsugamushi. Once a camp area is cleared the danger declines, except for men on patrols.

CONTROL: Measures for preventing tsutsugamushi consist mainly in avoiding mites. If possible campsites should be cleared or brushed out, the tall grass cut and the area thoroughly burned over before being occupied. Men should sleep in jungle hammocks or on cots off the ground. While working, they should be fully clothed, with sleeves rolled down and with leggings or trousers tucked into socks.

It is important to anticipate chigger attack and to apply repellents prior to exposure, especially in tsutsugamushi areas. Individuals exposed to chiggers are not aware of their presence for some hours after exposure. By the time the irritation is noticed, the damage is done; and even though attached chiggers are destroyed, the irritation from their bites will persist for several days or weeks, and infection with tsutsugamushi or a secondary infection from scratching may result.

GI repellent (a mixture of dimethylphthalate, indalone, and Rutgers 612) can be applied to the skin, but is more effective when applied to clothing. Apply a thin layer one-half inch wide along all openings of uniform on inside of neck, fly and cuffs of shirt, waist, fly and cuffs of trousers, socks above shoes, and all edges of leggings by drawing the mouth of the bottle along the cloth. Clothing may be treated several days before it is worn, and one application is effective until the uniform is normally changed for laundering. Care should be taken to avoid rubbing the repellent on any plastic surfaces, such as watch crystals which may become opaque. Under combat conditions, insect powder in the hair may also help to protect against mites.

On returning from a tsutsugamushi area, all men should bathe thoroughly, boil clothes, spray shoes and other gear with insecticide, or dust with insect powder. Every precaution should be taken to kill any infested mites that may be brought in and to avoid infecting additional mites in the area.

Rodent destruction by trapping or poison baits is of value in decreasing the wild animal host of the mites in camp areas.

MISCELLANEOUS MITES

Occasionally, mites belonging to other families may cause a temporary dermatitis in man. Some of these are normally parasites of other animals or even of insects, but occasionally they attack man. Rat and chicken mites are often offenders in this respect. Others feed on detritus, but may feed on man, causing a temporary skin irritation variously known as "grocer's itch", "copra itch", "grain itch", etc., depending on the associated material and the mite involved.

PLATE VII.

OTHER MITES OF MEDICAL IMPORTANCE

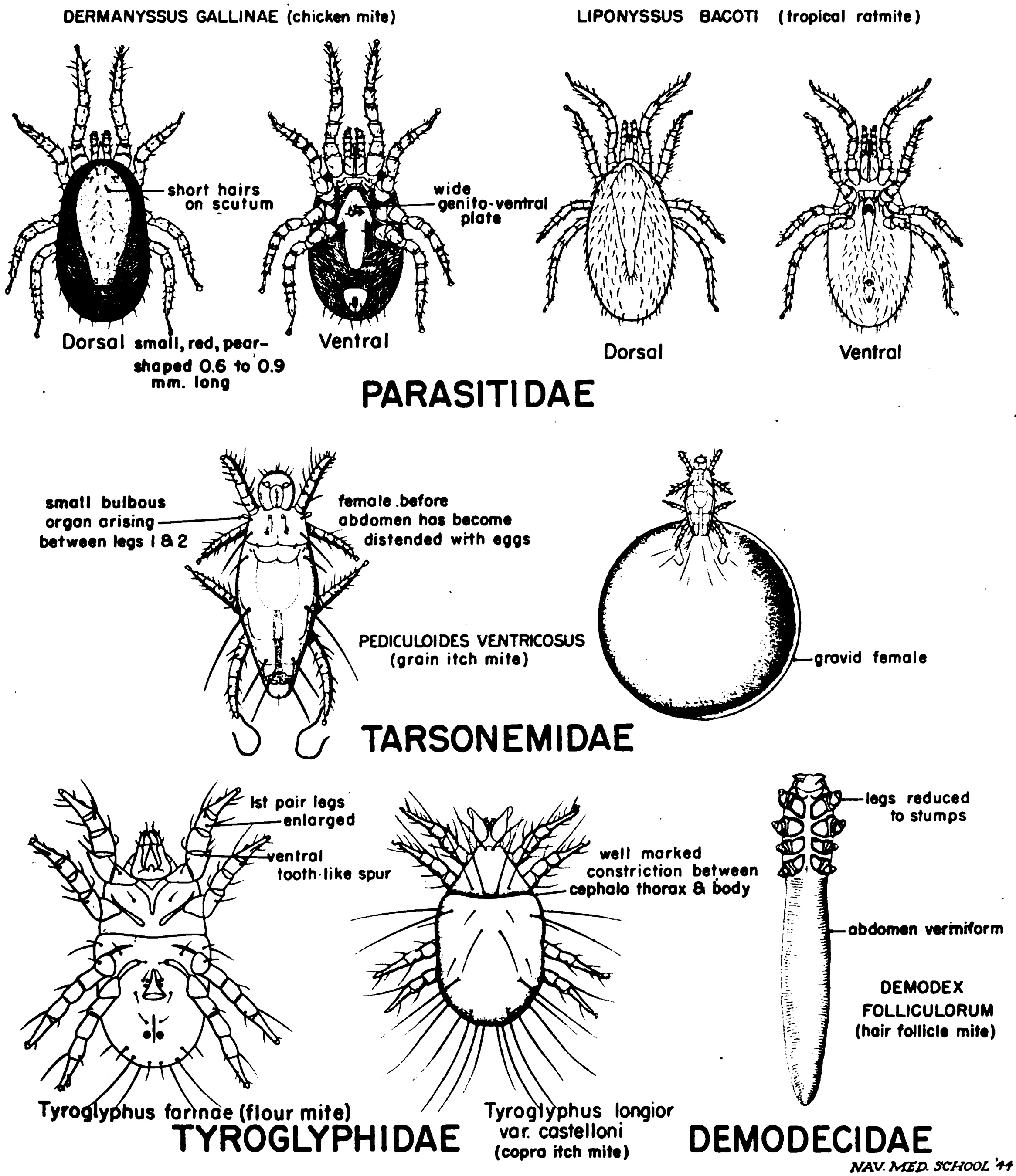
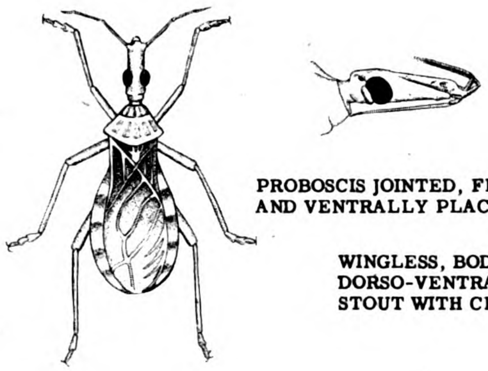
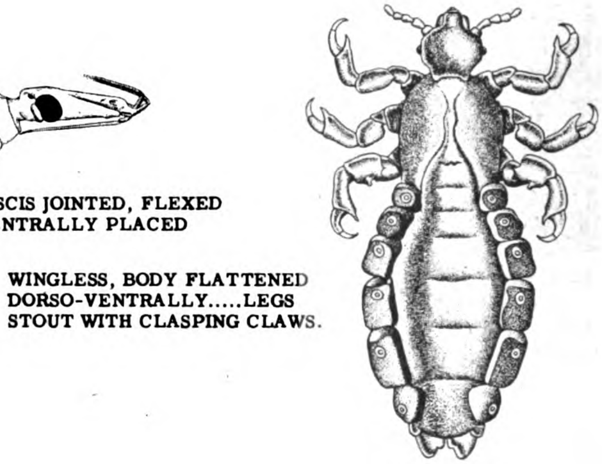


PLATE VIII.

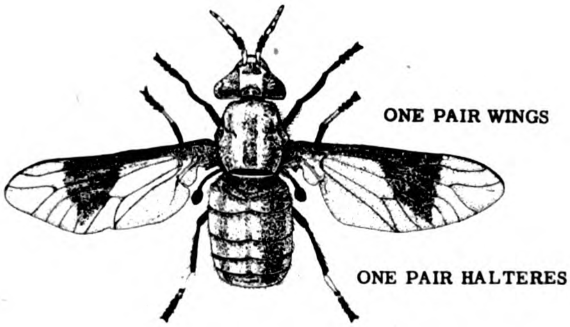
PRINCIPAL CHARACTERS FOR IDENTIFYING ORDERS OF INSECTS OF MEDICAL IMPORTANCE



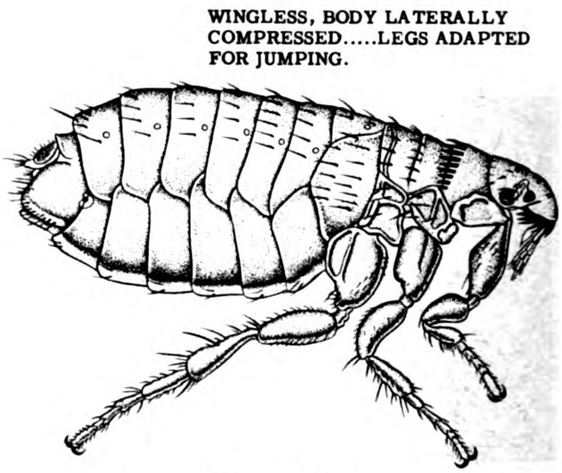
HEMIPTERA
(true bugs)



ANOPLURA
(sucking lice)



DIPTERA
(flies, gnats, mosquitos)



SIPHONAPTERA
(fleas)

CLASSES OF MEDICALLY IMPORTANT ARTHROPODS

CLASS INSECTA
(insects)

GENERAL CHARACTERISTICS.

Without question, insects are the most important of all arthropods from the standpoint of human disease. They are, therefore, studied in greater detail here than any of the foregoing arthropod classes. The members of the CLASS INSECTA have the body divided into three regions --- head, thorax, and abdomen. They have three pairs of legs and one pair of antennae.

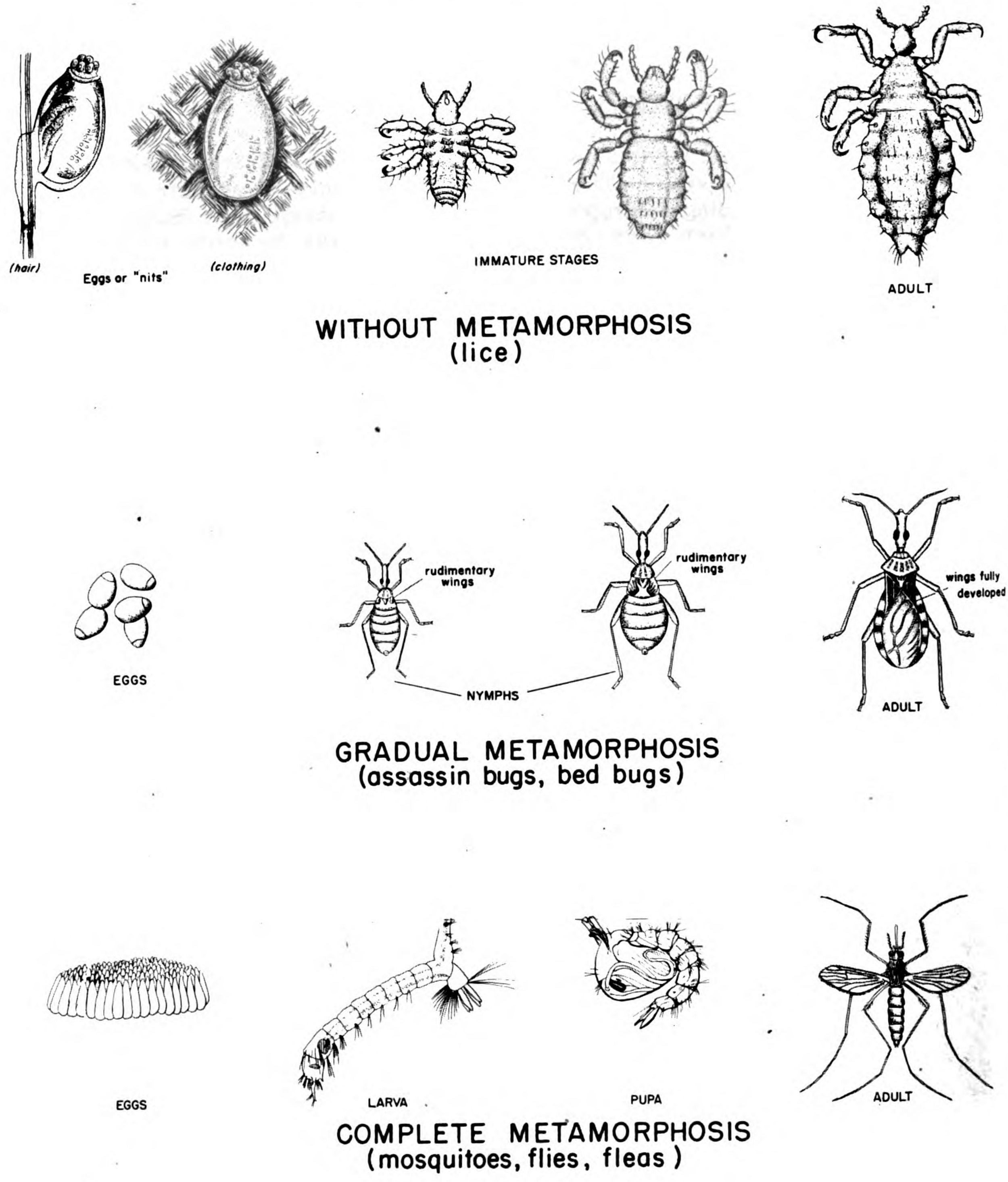
INSECT DEVELOPMENT - METAMORPHOSIS.

It is important to recognize that most insects undergo marked change in size, form, and structure during their development from egg to adult. This marked change in form during the life cycle of an insect is termed metamorphosis and may occur in several ways.

Since control measures may be directed against several stages in the life cycle of an insect, it is important to associate the immature and adult stages even though they may differ greatly in appearance. Thus a knowledge of the types of metamorphosis and an ability to recognize various immature stages is of practical importance in the control of insect-borne diseases. In many instances, species identification can be as readily accomplished by examining immature forms as by examining adults.

PLATE IX.

INSECT DEVELOPMENT



CLASS INSECTA

IMPORTANT TYPES OF INSECT DEVELOPMENT

1. Insects without metamorphosis (ametabola - without change).

In a few small groups of insects, the young as they hatch from the egg resemble the adult very closely, except for size. Since there is little or no change in form during their development, these insects are described as having no metamorphosis. Lice are common examples of this type of development.

2. Insects with gradual metamorphosis (paurometabola - with gradual change).

In other groups of insects, the young are very similar to the adults except for size and wing development. In those insects which have winged adults, the young have small wing pads which become increasingly larger with successive molts until the fully winged adult appears. The more developed the young insect becomes, the closer it resembles its parents. This type of development is termed gradual metamorphosis, since the change to the adult form is a gradual one.

The young of insects with gradual metamorphosis are called nymphs. They commonly have the same feeding habits as their parents and are frequently found together in the same situations. Control measures are thus the same for both adults and immature stages. Many important insect orders have this type of development, including the HEMIPTERA, some of which are medically important.

3. Insects with complete metamorphosis (holometabola - with complete change).

In this last group of insects are included those forms in which all the life-cycle stages are very different from each other. A complete change in appearance is involved in their development from egg to adult. In many of these insects, the mouth parts of the immature and adult forms are of totally different types, and the insects themselves may have entirely different feeding habits and live in different habitats. Hence, control measures applied against adults and immature insects may differ greatly in those groups undergoing complete metamorphosis.

In these forms, the eggs hatch into larvae (singular, larva) which are feeding forms. These larvae may live in soil, in water, or even develop as parasites in various animals. During their development, the larvae grow and molt a number of times; but in no case do the wings appear as external pads as they do in the nymphs of insects undergoing gradual metamorphosis. Once growth and larval development are completed, a striking change takes place as the larva transforms into the pupal stage. The pupa (plural, pupae) is a non-feeding stage in which a reorganization of internal organs takes place. Once this transformation into the adult form is completed, the mature or adult insect emerges from the pupal case. Among the many important orders having this type of metamorphosis are the DIPTERA (mosquitoes and flies) and the SIPHONAPTERA (fleas).

CLASS INSECTA

INSECT MOUTH PARTS

The most important way in which insects inflict damage as vectors of human disease is through their feeding or eating habits. Since insects feed in a variety of ways, it becomes evident that a knowledge of insect mouth parts is of prime importance in any study of insect transmission of disease.

Mouth parts of medically important insects may be classified as follows:

1. Chewing mouth parts.

Although chewing insects are not so common disease vectors as are sucking forms, they do illustrate the primitive type of mouth parts from which all other more specialized types have been developed. Some of them are associated with the mechanical transmission of disease agents (hymenolepiasis, moniliformiasis) and in one instance, at least, a chewing insect (flea larva) is involved in the biological transmission of a pathogen (dipylidiasis).

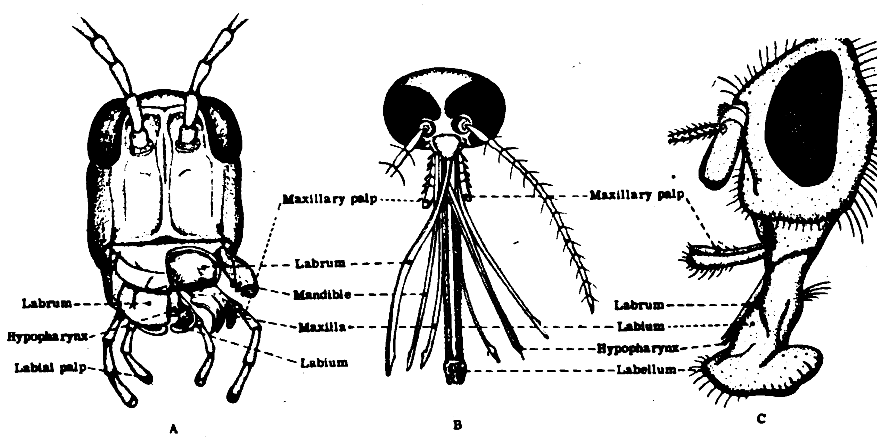


FIG. 22. Types of mouth-parts:
A. Primitive chewing mouth parts
B. Mouth parts modified for piercing
C. Mouth parts modified for lapping or sponging

2. Sucking mouth parts.

In the more specialized type of mouth parts discussed below, the same basic parts of the chewing type have been greatly modified to form organs for the ingestion of liquids.

(a) Piercing: This type of mouth parts is characterized by a tubular beak, or proboscis, enclosing several needle-like pieces known as stylets (mandibles, maxillae, hypopharynx, and labrum). The outer tube or proboscis is the modified labium which is usually a protective, sheath-like structure for holding the other parts. This type is found in the HEMIPTERA, ANOPLURA, SIPHONAPTERA, and most of the blood-sucking Diptera. All of these orders include insects which transmit disease agents which are at some time circulating in the blood of man.

(b) Non-piercing: This type is similar to the above, except that the stylets are not adapted for piercing. The term lapping or sponging is sometimes applied to this type. Insects with this type of mouth parts are often associated with the mechanical transmission of pathogens. The house fly is a good example.

CHEMICAL CONTROL OF INSECTS

The mouth parts of insects have a very practical bearing on the type of insecticide used in their control. For convenience, the types of chemical control used in medical entomology may be classified as follows:

A. Insecticides - substances that kill insects by their chemical action.

1. Stomach poisons

2. Contact poisons

3. Fumigants

B. Attractants - substances that lure insects to baits or traps.

C. Repellents - substances that keep insects away.

Stomach poisons are generally applied against chewing insects, but they may also be used for insects with sponging or lapping mouth parts. Such materials may be mixed with a food to form a poison-bait mixture, such as formalin and milk for house flies, and borax tablets for cockroaches. They may be sprinkled over runways of insects, so that some of the poison will be swallowed when the insect cleans its legs and antennae. Sodium fluoride is used in this way for cockroach control. Other common examples of stomach poisons include various phosphorous compounds and arsenicals, such as Paris green.

Since the majority of medically important insects have sucking mouth parts, they cannot usually be controlled by poisoning their food. Against these sucking insects contact insecticides are therefore used. Insecticides of this type are used in liquid or dust form to kill insects through bodily contact, or by entrance into the body through the spiracles. Examples of common contact insecticides include (1) organic substances, such as pyrethrum, rotenone, and nicotine; (2) synthetic organic preparations, such as DDT, certain thiocyanates, lethanes, and cyclohexylamines; and (3) sulfur and other dusts.

Gaseous substances used to kill insects are known as fumigants. The more common materials used include hydrocyanic acid gas, methyl bromide, naphthalene and many others. These gases are absorbed through the body-wall or the tracheal system and kill by asphyxiation.

Repellents are substances which prevent insect damage by interposing a chemical barrier between the insect and its host. In controlling disease vectors, they are

mainly used in the protection of the bodies of man and animals against insect attack. The best repellents are the more recently developed dimethylphthalate, isopropylcinnamate, Rutgers 612, and indalone preparations. Repellents are particularly important in war-time, because they are the only practical means for avoiding malaria and tsutsugamushi under actual combat conditions.

The present war, with its problems of insect-borne diseases, has stimulated the search for new materials to protect troops from annoying and disease-carrying insects. It is in the field of contact insecticides and repellents that the most startling progress has been made.

The newly developed repellents, dimethylphthalate, indalone, Rutgers 612, and isopropylcinnamate, are a great improvement over anything previously available. The present GI repellent, a mixture of the first three of these materials, in the ratio 6:2:2, is effective against a greater variety of insects than any one of the three used alone. There is often a great variation in the effect of the different repellents on different insect species. New repellent materials and new mixtures of repellents will undoubtedly be recommended as the result of extensive research in this field.

A new synthetic insecticide, DDT, offers many new possibilities in the field of insect control. Chemically, it is a white crystalline solid, relatively odorless, stable, insoluble in water, but soluble in most organic solvents. It acts relatively slowly, often requiring from 12 to 14 hours between exposure and kill. Insects may, therefore, be able to leave a treated area before dying and the actual kill may not be apparent. The unusual residual effect of DDT is one of its most remarkable and useful properties. The spray residue may kill insects that walk over it for weeks or even months after application. Its specific use against insects and arachnids is discussed in the sections dealing with those arthropods. It is available in a twenty-five per cent emulsion concentrate, in a ten per cent dust, and as pure DDT. A word of precaution is in order against the exclusive dependence upon DDT for controlling insects. It should be remembered that it is a very new insecticide and may have limiting and dangerous characteristics as yet unrecognized. Workers should avoid contact with oil solutions of DDT on the skin, and food should be protected from contamination. The possibility of a cumulative toxic effect upon man has not yet been definitely ruled out.

WARNING: Most materials used as insecticides are dangerous to humans if improperly handled. Labels on containers and instructions for usage should be read carefully for information on precautions in use, toxicity to man, and antidotes.

Stomach poisons, such as sodium fluoride and Paris green, are poisonous if taken internally in sufficient amounts and should be kept, plainly labeled, away from food, animals, and irresponsible persons.

Certain contact insecticides, such as nicotine sulfate and DDT, are also poisonous if taken internally and may even harm man if applied too heavily to the skin or inhaled in too large doses. The toxicity to man of DDT is greatly increased by solution in oils.

CLASS INSECTA

Key To The Orders Of Insects Of Medical Importance

1. Mouth parts adapted for chewing. . . . . ORTHOPTERA

   Mouth parts adapted for sucking. 2

2. Proboscis jointed, reflexed, and ventrally placed appearing as a single tube borne by the front part of the head. . . . . . .HEMIPTERA

   Proboscis not as above. 3

3. With one pair of wings, one pair of halteres. . . . . .DIPTERA

   Wingless insects. 4

4. Body flattened dorso-ventrally; legs stout, with clasping claws. . ANOPLURA

   Body laterally compressed; legs adapted for jumping. . . . . SIPHONAPTERA

Occasionally, insects belonging to orders other than those mentioned in the above key may be of some importance in annoying man, even occasionally in transmitting disease. Usually, these insects are of minor or very local importance, hence a complete discussion is not within the scope of this manual. The orders of minor medical importance include the COLEOPTERA, beetles; the LEPIDOPTERA, butterflies and moths; and the HYMENOPTERA, wasps, bees, and ants.

ORDER COLEOPTERA: Many beetles may serve as intermediate hosts of various helminth parasites of man and animals. Beetles which feed on fecal material as well as on cereals and other materials may readily act as intermediate hosts for the nematode worm, *Gongylonema pulchrum*; the acanthocephalans, *Moniliformis moniliformis* and *Macracanthorhynchus hirudinaceus*; and the rat tapeworm, *Hymenolepis diminuta.* Other Coleoptera, such as the blister beetles, may cause a blistering of the skin from simple contact, or when the beetle is crushed on the skin. Cantharidin, a local irritant occasionally used in medicine, is prepared from certain species of blister beetles.

ORDER LEPIDOPTERA: The caterpillars of many species of butterflies and moths possess urticating hairs. When these caterpillars molt, myriads of tiny barbed hairs are shed and blown about by the wind. When they come in contact with the skin, a severe dermatitis results; when they are breathed in, the hairs may cause a severe lung irritation.

ORDER HYMENOPTERA: The stinging insects - hornets, wasps, bees, and ants belong to this group. Certain ants, which lack a sting, spray their venom into wounds made by their mandibles; others merely inflict painful bites. Individuals vary in their reaction to insect venom. In some cases, death has been caused by bee stings, in particularly susceptible persons.

CLASS INSECTA

ORDER ORTHOPTERA
(cockroaches, grasshoppers, crickets)

The ORTHOPTERA are characterized by their chewing mouth parts and two pairs of wings. The outer pair are parchment-like, covering and protecting the inner membranous wings which are folded fan-like when at rest. Metamorphosis is gradual.

FAMILY BLATTIDAE
(cockroaches)

The BLATTIDAE, or cockroaches, have legs modified for running and long antennae. Their dorso-ventrally flattened bodies are well adpated for hiding in narrow crevices.

RELATION TO MAN: Because of their habits, cockroaches have been under suspicion as mechanical vectors of certain diseases. They have filthy habits and feed on the excretions of man, as well as on nearly all the foods consumed by him. The causative organisms of tuberculosis, leprosy, amebic dysentery, bacillary dysentery, and cholera have been found to pass unharmed through the cockroach's intestinal tract. Contamination of food may be accomplished by contact, as well as by fecal deposits. Cockroaches may also act as intermediate hosts of certain parasitic worms - *Moniliformis moniliformis*, *Gongylonema pulchrum*, and *Hymenolepis diminuta.*

LIFE CYCLE AND HABITS: Cockroaches are much slower in their development than other common insect pests. Their eggs are laid in more or less rigid capsules, or oötheca. Those of the German roach may hatch in about 28 days, and the entire life cycle can be completed in 90 days. Growth is influenced greatly by temperature, humidity, and available food; hence the length of life cycle is extremely variable. Roaches are nocturnal in habit, hiding during the day in sheltered, darkened places. They forage at night and when disturbed disappear into crevices or holes. Knowledge of where they conceal themselves is usually the key to their control.

CONTROL: Thorough cleanliness and protection of food supplies is important in roach control. In loosely constructed buildings or in areas of mild climate, reinfestation is common and control must be periodic.

Sodium fluoride, although poisonous to man, is the best roach remedy. It should be lightly dusted or blown into hiding places or sprinkled where roaches run most frequently. This poison is also available in crayon form for ready application. It kills as a stomach poison when the insect cleans the material from its legs and antennae. The powder should be applied in the evening and left for 2-3 days. Applications should be repeated at intervals of one to two weeks, or until the roaches disappear.

Borax powder can be used in the same way, or as tablets when mixed with some inert material. It is not so poisonous and is not so effective as the sodium fluoride. Phosphorous pastes may also be used.

Galleys and mess halls may also be treated with DDT. The hiding places can be sprayed with 5% DDT in kerosene in an emulsion, or dusted with 10-25% DDT in talc.

CLASS INSECTA

ORDER HEMIPTERA
(true bugs)

The HEMIPTERA have a jointed suctorial proboscis attached anteriorly which, when not in use, is flexed under the head. The winged members of this order have each of the front wings modified into a thickened basal portion and a membranous distal portion. Metamorphosis is gradual.

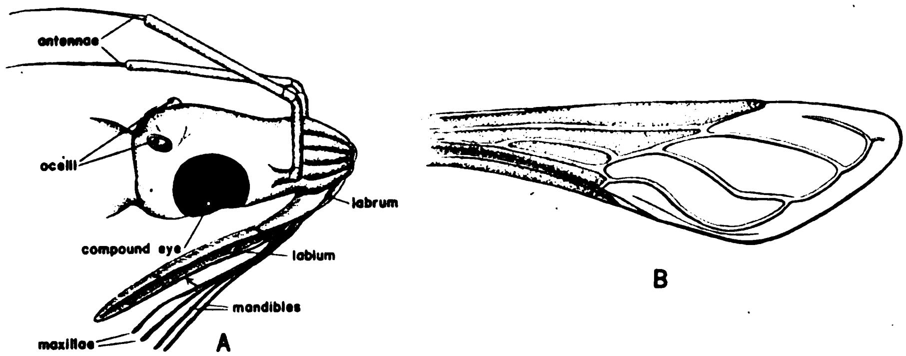


FIG. 23. A. Head and mouth parts of a hemipteron.
B. Wing of a hemipteron.

FAMILY REDUVIIDAE
(conenose bugs, assassin bugs)

The bugs of this family have the anterior portion of the head elongated and cone-shaped. The antennae are long and made up of four segments, and the proboscis is three-segmented.

RELATION TO MAN: Members of several reduviid genera, including Triatoma, Rhodnius, and Panstrongylus, are important as vectors of the causative organism (Trypanosoma cruzi) of Chagas' disease, or South American trypanosomiasis.

LIFE CYCLE AND HABITS: The eggs are deposited in dusty corners of houses or in nests and burrow of hosts. After an incubation period of from eight days to a month, the first instar nymphs emerge. They secrete themselves in dark crevices and other hiding places during the day. A blood meal is necessary before each molt, the time spent in each instar being about 40 to 50 days. The entire life cycle usually requires a year or more.

The adults of both sexes bite and may attack man. The bite of a blood-sucking reduviid is usually so painless that one who is bitten during sleep is not awakened. After the blood meal, which may last from a few minutes to half an hour, the insect deposits a small amount of liquid feces on the skin near the puncture made by the proboscis. Reduviids which take blood from persons infected with the causative agents of Chagas' disease usually harbor these organisms in their bodies for life. Infection of new individuals takes place by the scratching or rubbing of the infective feces into the excoriated skin at the site of the bite.

FAMILY REDUVIIDAE

CONTROL: Destruction of reduviids is very difficult. Mosquito nets and screened quarters offer protection against the adults and the larger nymphs.

CLASSIFICATION OF IMPORTANT GENERA: The important genera are separated by the position of the antennal insertion. In *Rhodnius*, the insertion is at the tip of the head; in *Triatoma*, the insertion is midway between the compound eyes and the tip of the head; while in *Panstrongylus*, the insertion is near the compound eyes.

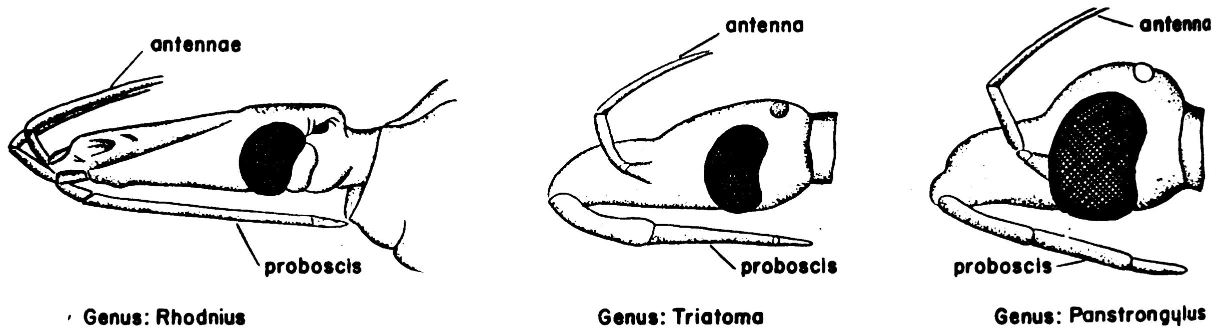


FIG. 24. Heads of *Rhodnius*, *Triatoma*, and *Panstrongylus*.

FAMILY CIMICIDAE
(bedbugs)

The members of this family have broad, flat, reddish-brown bodies and are devoid of wings, except for a pair of spiny pads which represent the rudimentary first pair of wings. The eyes project prominently at the sides of the head. The flexible antennae are constantly moved about in front of the head and appear to be four-jointed because the basal segment is very minute. The four-jointed beak also has a very inconspicuous basal segment and is folded under the head. A nasty pungent odor is associated with the group.

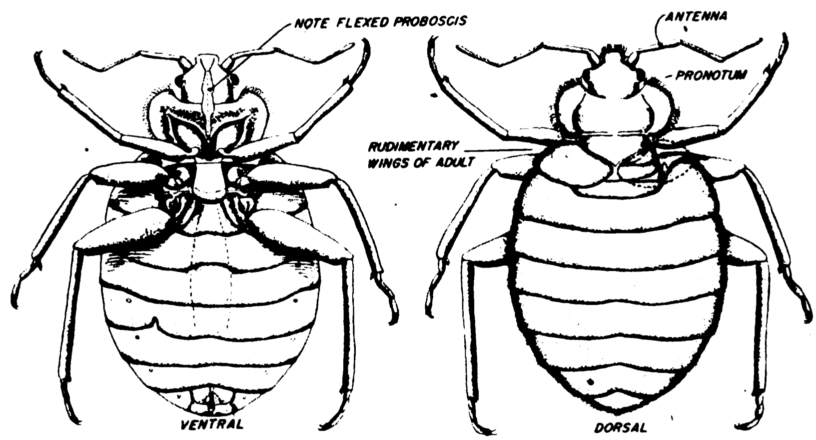


FIG. 25. Adult *Cimex lectularius*, the bedbug.

FAMILY CIMICIDAE

RELATION TO MAN: Because of their blood-sucking habits, bedbugs are pests of man, but they have not been incriminated in the natural transmission of any disease.

LIFE CYCLE AND HABITS: The eggs, which are large and yellowish-white, are deposited in groups of 100 to 250 in cracks and crevices, and very commonly under wall-paper. The incubation period may be from 7 to 30 days. The nymphs molt five times, a feed of blood being necessary before each molt. With the last molt, the wing pads, characteristic of the adult, appear. Bedbugs are nocturnal insects that hide in crevices and cracks during the day. Old-fashioned wooden bedsteads afford abundant hiding places. Bedbugs are gregarious, large numbers of adults and nymphs being found together.

Persons are affected differently by the bites of bedbugs. Some react with marked swellings, while others show no reaction. The fact that bedbugs must feed at least five times, either upon the same or different hosts, in order to reach maturity has placed these insects under grave suspicion as possible vectors of disease.

CONTROL: Light infestations of bedbugs can sometimes be eliminated by the thorough application of ordinary fly sprays or pyrethrum-kerosene mixtures. Frequent inspections and local treatments will prevent a general infestation from developing. A very effective material for the control of bedbugs is DDT which is especially valuable because of its residual effect in preventing reinfestation. It may be applied as 5% DDT in kerosene in an emulsion, or as a 5% dust. Care must be taken to apply the material to bedsteads, springs, mattresses, and to the floors and walls near the bed, especially all crevices in which the bugs may hide during the day. The DDT-kerosene mixture or emulsion should be applied in a spray in sufficient quantities to obtain a heavy, even deposit of DDT. About three gallons of spray is required to treat all beds and the side walls of an ordinary 74-man barrack. Barracks so treated have been found to remain free from bedbugs for as long as four months.

General infestations of bedbugs can be controlled by the use of hydrocyanic acid gas as a fumigant (Manual of the Medical Department, Chapter 18, Section 8, paragraph 2887). In no case should fumigation with hydrocyanic acid gas be undertaken by persons untrained in its use.

HCN is a deadly poison and must be handled with extreme care and only by responsible persons experienced in its use.

CLASS INSECTA

ORDER ANOPLURA
(sucking lice)

The sucking lice are small, wingless ectoparasites with dorsal spiracles and soft bodies. The tibiae and tarsi are fitted for grasping hairs. Their development is without metamorphosis. The skin-piercing stylets of the mouth parts are normally retracted into the head and are everted only during the blood-sucking process. The order includes about 400 species, but only two species suck the blood of man.

FAMILY PEDICULIDAE

This family includes both species feeding upon man. These lice are characterized by having conspicuous eyes, depressed bodies, and indistinctly segmented thoraces.

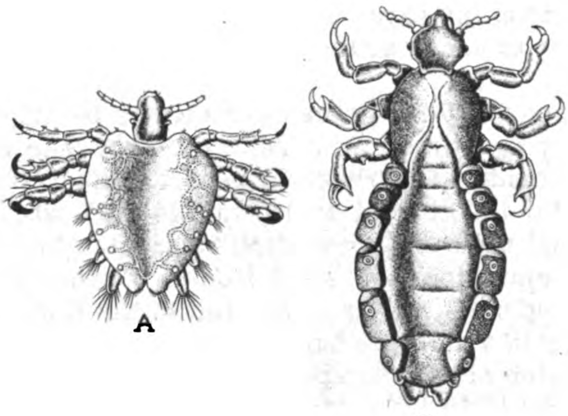


FIG. 26. A. Phthirus pubis, the crab louse.
B. Pediculus humanus, the body louse.

RELATION TO MAN: The bite of the head and body louse, Pediculus humanus, provokes rosy swellings and, coupled with the ensuing scratching, produces the characteristic scarring and bronzing of the skin referred to as "vagabonds' disease." This same species transmits epidemic typhus, a disease caused by Rickettsia prowazeki, which produces a case fatality varying from as low as 5% to as high as 70% in epidemics among undernourished refugee populations. Transmission is accomplished by scratching the infected crushed lice or their feces into the site of the bite or into the excoriated skin. The disease is not transmitted by the bite alone.

Pediculus humanus also transmits louse-borne relapsing fever, a spirochetal disease (Borrelia recurrentis). For successful transmission, the infected lice must be crushed and rubbed into the abraided skin or into the conjunctiva of the eye. Neither the feces nor the bite are infectious. A third louse-borne disease, trench fever, is of minor importance, at least under present combat conditions. The causative agent is believed to be a rickettsial body, Rickettsia quintana.

The second species, Phthirus pubis, the pubic or crab louse, infests the pubic regions, causing intense itching. In hairy individuals, these lice may infest the entire body, even the eyebrows. They have not been implicated in the transmission of disease.

LIFE CYCLE AND HABITS: The lice infesting man require a period of roughly three to four weeks for their development. The pubic lice and the "head strain" of Pediculus humanus attach their eggs ("nits") to hairs, while the "body strain" of P. humanus glues its eggs to fibers in the seams of clothing. These eggs hatch in about a week. In unused clothing, however, body lice eggs may remain viable but unhatched for as long as five weeks.

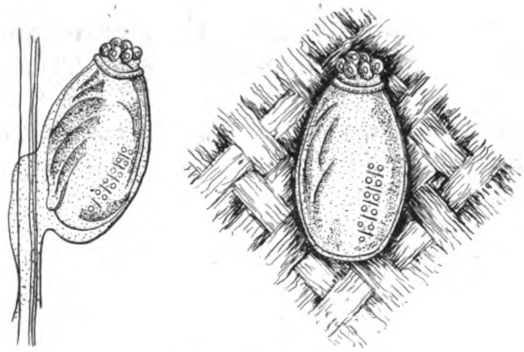


FIG. 27. Eggs of lice.

The front of a louse's head is produced into a very blunt snout bearing a ring of recurved hooks. This ring is called the haustellum. When the louse feeds, it presses its haustellum against the skin, rolls out the hooks until they are firmly attached, and then forces the stylets deep into the skin. Since these stylets are normally retracted within the head, they are not seen in ordinary whole mounts.

CONTROL: The new synthetic insecticide, DDT, is more highly effective and longer lasting than any previously known louse treatment. When applied as a powder (Navy insecticide powder, S13-451), it will destroy crab lice as well as head and body lice. DDT can also be used as a liquid preparation applied as a spray for head lice and crab lice (see formula given for scabies control).

Since the body louse is usually found in clothing, examination for lice and nits should be made in the seams and folds of the clothing, especially the underwear. DDT powder should be sifted over the entire inner surface of the underwear, paying especial attention to the seams. The inside of the shirt, trousers, and hat should be treated in the same way. About 1 ounce of powder will be necessary for one application. The powder can also be used as a prophylactic measure for persons mingling with louse-infested troops or civilians. Bedding should also be dusted by applying DDT between the sheets and blankets and on the mattress. Although it is not an ovicide, it remains effective longer than the usual incubation period for louse eggs and, therefore, kills the lice as they emerge from the eggs. Its most outstanding feature is its long lasting quality - it will give almost complete protection against lice for three weeks and effective control for even longer periods.

ORDER ANOPLURA

Clothing impregnated with DDT will kill lice even after having been laundered several times (after nine weeks of wear and nine washings). Impregnation is accomplished by dipping the clothing in a volatile solvent containing 1-2% DDT or in an aqueous emulsion, wringing lightly, and then hanging the clothing up to dry. Methods for large scale treatment of clothing have also been developed.

Derris powder is also effective in controlling head and pubic lice. It can be applied in an ordinary salt shaker, care being taken not to get powder into the eyes. About one teaspoonful can be used on each head, and the powder allowed to remain for ten days without washing. The powder may also be applied in three applications at weekly intervals.

Ten percent tincture of larkspur, liberally applied and the application repeated in eight days, or mercurial ointment may also be used against pubic lice. Against head lice, an equal mixture of kerosene and olive oil warmed together and daubed thoroughly into the hair and scalp with a gauze swab and left for several hours is effective. Great care must be exercised to avoid reinfestation from discarded clothing or bathtowels.

For large-scale control of body lice in clothing, methyl bromide is a very satisfactory fumigant. A knock-down portable fumigation vault of 325 cubic feet capacity, equipped with circulation and exhaust systems, is used. The methyl bromide is introduced from the outside with patented applicators at the rate of three pounds per charge. Clothing and blankets are placed on trucks or on pole-shelves in the vault and fumigated for 45 minutes. Five minutes after the gas has been exhausted from the vault, the clothing may be removed and worn. The gas has no deleterious effect upon delicate fabrics or upon metal or leather objects. While the clothing is being fumigated, the men should be scrubbing and thoroughly disinfesting themselves. Since the fumigation vault will hold the personal effects of about 65 men, a twelve-head shower should be provided to care for the bathing needs of a like number of men.

Methyl bromide is also supplied in 2-ounce capsules to be used in fumigation of individual barracks bags. The methyl bromide capsules are placed in special, gas-tight bags with the clothing, and the capsules are broken by outside pressure. In 45 minutes the clothing is removed and aired. More complete directions are given on the capsule.

ORDER SIPHONAPTERA
(fleas)

<u>GENERAL CHARACTERISTICS:</u> Fleas form a well-defined group, easily distinguished from all other insects, both by their structure and their habits. All are ectoparasites of birds and mammals. They are small, brown, hard-bodied insects, completely devoid of wings, a deficiency partly compensated for by their powerfully developed legs especially adapted for jumping. Unlike most parasites, they are very active and nimble and are capable of jumping upwards to a height of seven inches and horizontally nearly twice that distance. The laterally compressed bodies and

numerous stout, posteriorly-directed spines enable them to move readily through the hairs or feathers of their hosts. The antennae are short, three-segmented,and knob-like, partly concealed and protected in grooves at the sides of the head. True compound eyes are lacking; but some species possess degenerate eyes without distinct facets, while others are completely blind. In some species, a conspicuous row of very stout spines, or "comb," is located just above the mouth parts and on the pronotum. The mouth parts are especially adapted for piercing the skin and sucking blood, which is the only food known to be taken by adult fleas of both sexes. Metamorphosis is complete.

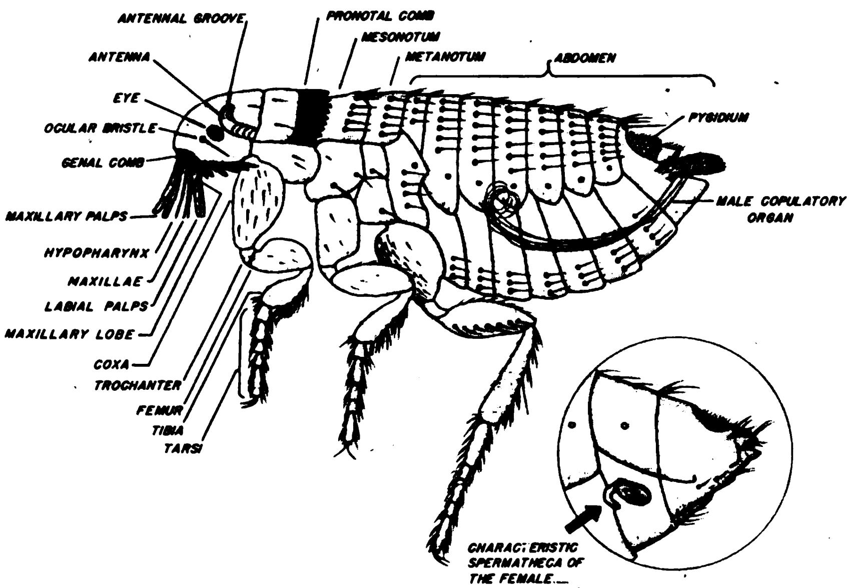


FIG. 28. Anatomy of a Flea.

RELATION TO MAN: Like most other blood-sucking parasites, fleas are intimately connected with the transmission of disease. They are of greatest importance in the transmission of bubonic plague, which fact alone is sufficient to rank fleas among the most important insect enemies of man. They also transmit endemic or murine typhus and act as the intermediate hosts of certain parasitic worms. Gravid females of the peculiar "chigoe" or burrowing flea (*Tunga penetrans*) penetrate the skin to complete their development, causing skin lesions on the feet of man and other animals.

LIFE CYCLE AND HABITS: Most fleas remain on their hosts less constantly than do lice, but they visit their hosts more frequently than do bedbugs. The nest or burrow of the host is the home of the egg, larva, and pupa, and frequently of the young or the ovipositing adult. The larvae develop and pupate in the nests or dens, and it is significant that those mammals which have no permanent habitation, such as the monkey and deer, are nearly free from fleas, although they seldom lack lice. The fact that fleas leave the body of a dead host as soon as it becomes cold is of particular importance in the spread of flea-borne diseases.

ORDER SIPHONAPTERA

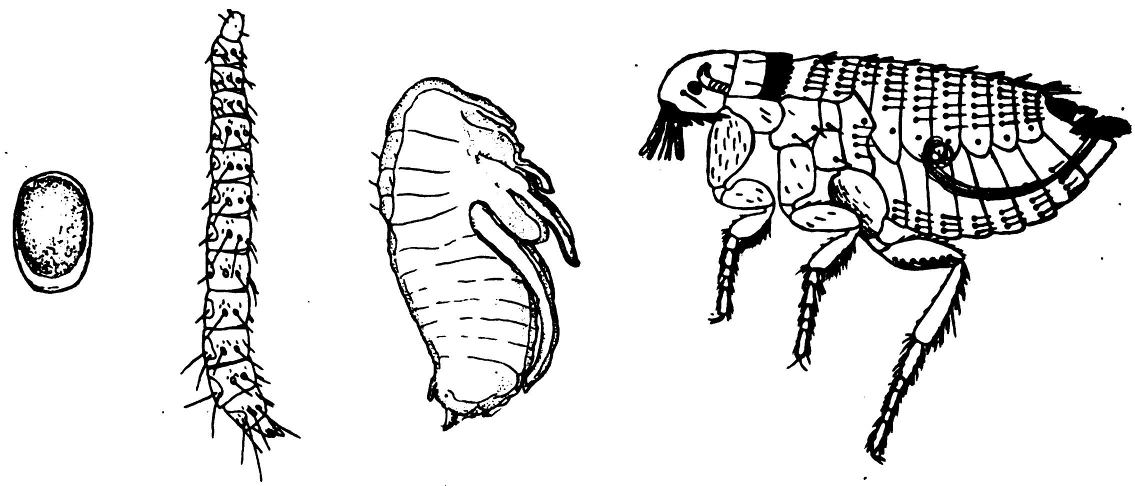


FIG. 29. Life-cycle of a flea. A. Egg. B. Larva. C. Pupa (removed from cocoon). D. Adult.

Eggs: These are oval, pearly white objects dropped at random in the fur of the host or in the dust and debris in cracks in floors, under rugs, or in nests or burrows. The incubation period varies from two to twelve days.

Larvae: Flea larvae are tiny, cylindrical, maggot-like creatures with neither legs nor eyes. They have brown heads and whitish bodies which are provided with rather sparse, bristly hairs which aid them in crawling. The body is terminated by a pair of tiny hooks. Under favorable conditions of temperature and humidity, the larvae pass through two molts and enter the pupal stage in ten to twelve days.

Pupae: When they are ready to change into pupae, the larvae spin little silken cocoons which are somewhat viscid so that particles of dust and lint adhere to them. The adults may emerge from the pupae in about five to fourteen days, but may require longer at low temperatures.

Unlike most blood-sucking insects, fleas feed at frequent intervals, usually at least once a day and sometimes much oftener than this. The frequent biting is due to the fact that fleas are very easily disturbed while feeding and seldom complete a meal at one bite. Fleas frequently feed even when their digestive tracts are already filled, and they may pass practically unaltered blood in their feces. Virulent plague bacilli rubbed into recent flea bites may result in infection of man or animal, but the usual method of plague transmission is by regurgitation. The rat flea, after feeding on an infected animal, often has its digestive tract completely blocked by solid growths of plague organisms. Such "blocked" fleas are unable to ingest more blood, but, in attempting to do so, they regurgitate great quantities of plague germs into their victims. Fleas may remain infective for a long time, but many fleas die when "blocked," especially in hot or dry weather, since they are unable to overcome the effects of desiccation by imbibing fresh blood.

ORDER SIPHONAPTERA

Probably the smallest flea known is the famous "jigger," sand flea, or "chigoe." The chigoe is one of the most annoying pests of tropical and subtropical countries where it occurs in immense numbers. The adults are fond of warmth and drought and may be found in dry dust in and about human habitations.

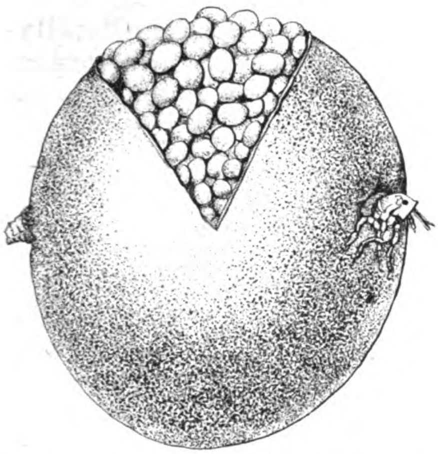


FIG. 30. Tunga penetrans distended with eggs.

When the female becomes fertilized, she seeks out a suitable host and burrows into the skin, particularly between the toes, under the toenails, and in the tender parts of the feet. Here, nourished by the host's blood, the eggs begin to develop. The abdomen swells almost to the size of a pea. The posterior end of the flea is flush with the surface of the host's skin. The eggs mature and are expelled through the tip of the abdomen; the female then shrivels up and drops out or is expelled by ulceration. The treatment for this flea when embedded in the tissues is not very satisfactory. Each flea may be removed under aseptic conditions by enlarging the opening with a clean needle and carefully removing the entire flea. The wound should then be thoroughly sterilized and dressed.

CONTROL: To combat fleas effectively, it is essential to determine the source of the infestation, to treat or destroy the animal host, and to destroy the immature stages of the flea in the dust on floors or in the burrows of rodents. In houses or barracks, bare floors can be wiped with a mop moistened with kerosene, and the process repeated again in two or three weeks. Rooms can be treated by sprinkling five pounds of flake naphthalene on the floor and closing the room for twenty-four hours. The naphthalene can be swept up and used in treating successive rooms. Fleas on dirt floors can be controlled by liberal application of coarse salt and then wetting it down, or by application of creosote or fuel oil.

Pet dogs and cats are often a source of flea infestation. Fleas on these animals can be controlled by dusting every two weeks with derris powder or fresh pyrethrum powder. Dogs treated with a five per cent DDT dust have been completely freed of fleas and protected from reinfestation for periods of four to seven days. The use of DDT in the control of other fleas, especially in the burrows of rodents, may prove of some value in plague control.

GI repellent may be applied to the exposed skin to protect individuals from fleas. It should also be applied to the clothing by spraying two to four ounces on the outside of the garments. This is important when going into flea-infested areas.

CLASSIFICATION: The differentiation of genera is based largely on the presence or absence of ctenidia or combs on the head or pronotum, the number of rows of bristles on the abdominal segments, the presence or absence of eyes, the position of the ocular bristle, and many other minor characters. Most species of fleas are

normally closely confined to particular kinds of hosts, only a few species being able to thrive on a variety of hosts. If the host and geographic locality are known, the number of species to be considered is comparatively small.

From the medical viewpoint, the fleas of interest are those which are commonly found on rats and other rodents subject to plague and endemic typhus, and those which attack man. With this in mind, the plate on page 53 diagrammatically shows how they may be broken down into three simple groups and gives a representative host upon which the fleas of each group are often found. A key to the genera of medical importance is given below.

Key To The Medically Important Genera Of Siphonaptera

1. The three thoracic tergites together shorter than the first abdominal tergite. 2
   The three thoracic tergites together longer than the first abdominal tergite. 3

2. Hind coxa with a patch of small spinules on its inner side. . . . Echidnophaga
   Hind coxa without patch of spinules on inner side. . . . . Tunga

3. Eyes well-developed. 4
   Eyes vestigial or absent; both pronotal and genal combs present 9

4. Neither pronotal nor genal combs present. 5
   Pronotal comb, at least, present. 6

5. Mesopleuron with only one internal rod-like thickening, which extends from the insertion of the coxa forward to the anterior border. . . . . .Pulex
   Mesopleuron with two internal rod-like thickenings, one extending forward, the other upward. . . . . Xenopsylla

6. Both pronotal and genal combs present. .7
   Pronotal comb present but genal comb absent. 8

7. Genal comb running horizontally along lower border of gena. .Ctenocephalides
   Genal comb running obliquely across gena. . . . . Spilopsyllus

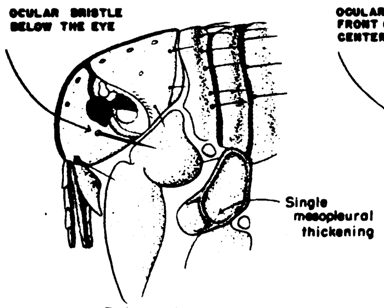
8. Third segment of antennal appendage distinctly segmented both anteriorly and posteriorly. . . . . Ceratophyllus
   Third segment of antenna distinctly segmented only on the posterior side. . . . . Hoplopsyllus

9. Posterior edge of the tibiae with about eight short and several long bristles, which do not resemble a comb. . . . . .Ctenophthalmus
   Posterior edge of tibiae with about twelve short and three long bristles, the short bristles forming a sort of comb. . . . . Ctenopsylla

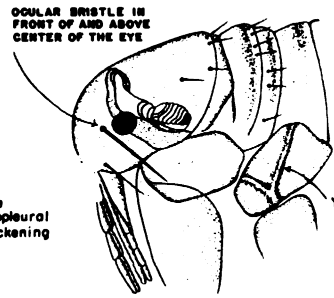
PLATE X

PRINCIPAL CHARACTERS FOR IDENTIFYING FLEAS OF MEDICAL IMPORTANCE

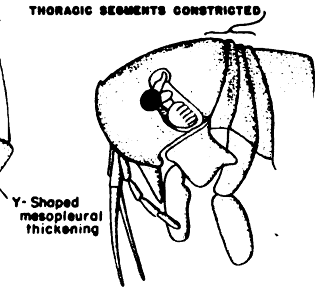
I. FLEAS WITHOUT PRONOTAL AND GENAL COMBS



Pulex irritans
(human flea)

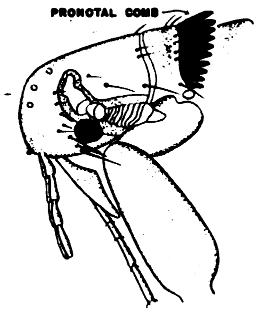


Xenopsylla cheopis
(rat flea)



Tunga penetrans
(chigoe, sand fleas of man and pigs)

2. FLEAS WITH PRONOTAL COMBS ONLY

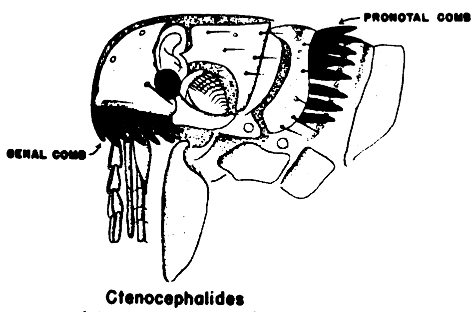


Ceratophyllus
Diamanus

(rodent fleas......squirrels, rats, marmots)

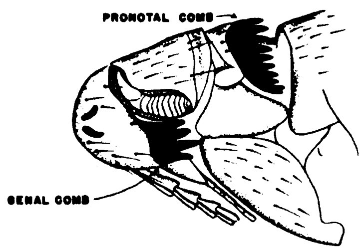
3. FLEAS WITH PRONOTAL AND GENAL COMBS

a. with eyes



Ctenocephalides
(dog and cat fleas)

b. without eyes



Ctenopsylla
(rodent fleas.......mice, rats)

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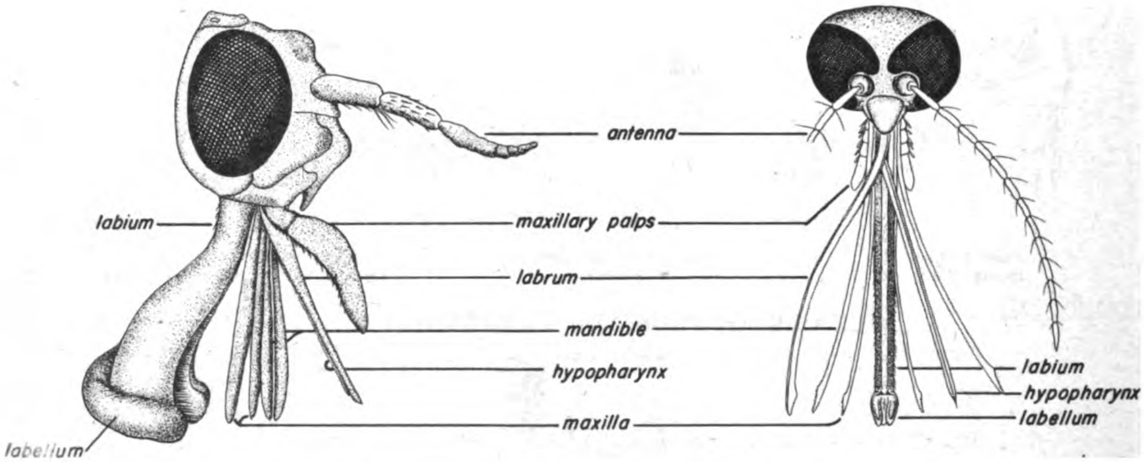
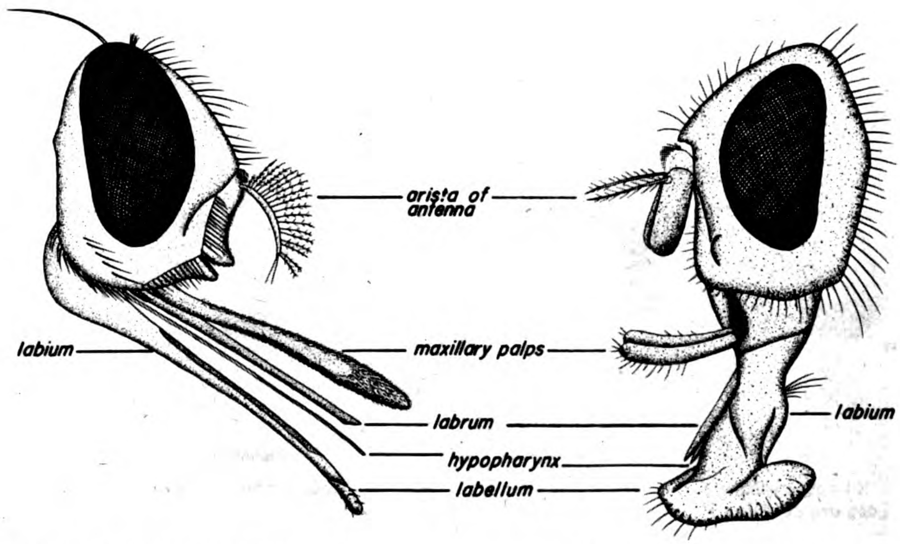
PLATE XI

TYPICAL MOUTH PARTS *of* MEDICALLY IMPORTANT DIPTERA



(A) BLADE-LIKE TYPE
CHRYSOPS

(B) STYLET TYPE
AEDES, CULEX



(C) LABIUM-PIERCING TYPE
GLOSSINA

(D) NON-PIERCING TYPE
MUSCA SARCOPHAGA
LUCILIA CALLIPHORA

CLASS INSECTA

ORDER DIPTERA
(flies, mosquitoes, gnats, midges)

GENERAL CHARACTERISTICS: To this order belong vectors of some of the most important diseases of man - malaria, yellow fever, dengue, and African sleeping sickness. They possess one pair of functional wings with rudiments of a second pair present in the form of short, knobbed organs known as halteres. All Diptera have complete metamorphosis. The larvae are legless and often wormlike, and not infrequently they are found in the tissues of man, causing myiasis. All Diptera have sucking mouth parts, of which two general types may be recognized: piercing and non-piercing. Any dipterous insect possessing mouth parts capable of piercing the skin of man must be regarded as a potential vector of blood-inhabiting, pathogenic microorganisms; on the other hand, insects with non-piercing mouth parts obviously cannot be responsible for introducing infection directly into the body except through previously injured surfaces. Thus, by inspection of mouth part structure alone, one may estimate the disease-conveying potentialities of any given insect.

The accompanying illustration shows three varieties of the piercing type -(A), (B), and (C) with the various structures dissected out. Normally, in the bladelike type (A) only two prominent structures are visible, the labium and the maxillary palps. The labium ensheathes the piercing and cutting mouth parts which consist of a pair of mandibles, a pair of maxillae (flat, bladelike and capable of lacerating), and two unpaired, lancetlike organs, the labrum and hypopharynx, also capable of piercing. The approximation of the labrum and the mandibles forms a food-canal up which blood is drawn. The salivary secretions are poured out through a duct in the hypopharynx. The maxillary palps are sensory in function and do not serve as cutting organs. This type is found in the families Tabanidae, Psychodidae, Ceratopogonidae, and Simuliidae.

Similar cutting and piercing organs are contained in the labium in the stylet type (B), except in this case the parts are long and slender and capable of particularly deep penetration. Normally, one sees only the maxillary palps and the long, rounded labium, this latter together with the enclosed parts being known as the proboscis. The labium does not take part in cutting in either type A or B. Mosquitoes are common examples of the stylet type.

In type (C), the labium holds in a "labial groove" only the labrum and hypopharynx, maxillae and mandibles being absent. In this case, the labium enters the wound and functions as an efficient piercing organ. The tsetse fly, stable fly, and horn fly have this type of piercing mouth parts. All three types illustrated are mouth parts of females. In many genera, similar structures in males are reduced and are unable to carry on the blood-sucking function.

In the non-piercing type (D), the labium is a thick, fleshy appendage enclosing a labrum and a hypopharynx, neither of which is capable of cutting. The fleshy padlike labellum merely acts as a "lapping" or "sponging" organ and is highly efficient in the mechanical transfer of pathogenic organisms.

ORDER DIPTERA

For purposes of convenience in identification, DIPTERA are grouped here into three suborders distinguishable by the antennal characters of the adults:

1. SUBORDER ATHERICERA - includes the common house fly and related flies. Some are important in the mechanical transmission of disease, and the larvae of many are myiasis-producing. Others are vicious biters and pests of man. One genus, Glossina, contains the vector of African sleeping sickness. The antennae of the Athericera are generally three-segmented. The first two segments are short and may be seen only on very close inspection. The third is much larger and bears an arista, a bristle or feather-like structure, on its dorsal surface. This arista is the characteristic structure of the Athericera.

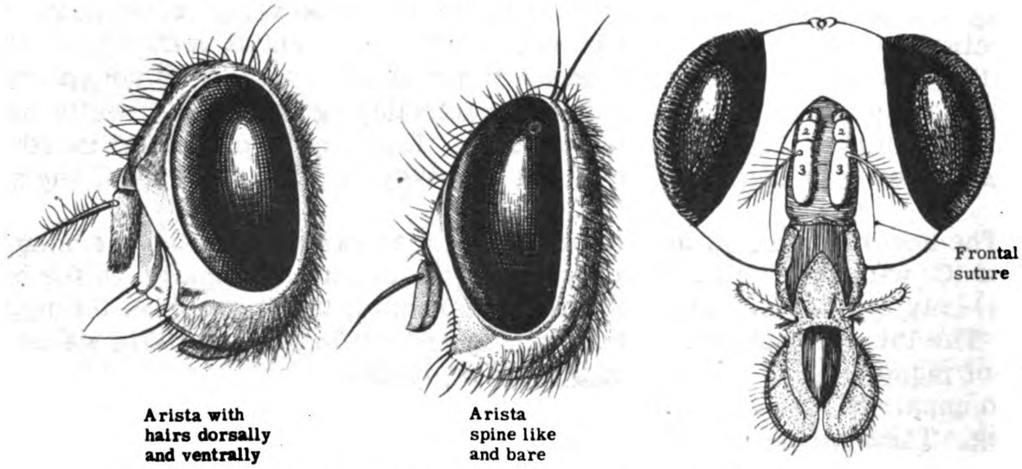


FIG. 31. Antennal characters of the suborder Athericera.

2. SUBORDER BRACHYCERA - includes the horse flies and deer flies. One blood-sucking genus, Chrysops, includes vectors of tularemia, a bacterial disease, and loaiasis, a filarial disease. The remainder are important to man only as pests, many being non-bloodsuckers. The Brachycera may be recognized by their three-jointed antennae which are variously formed and usually held horizontally erect.

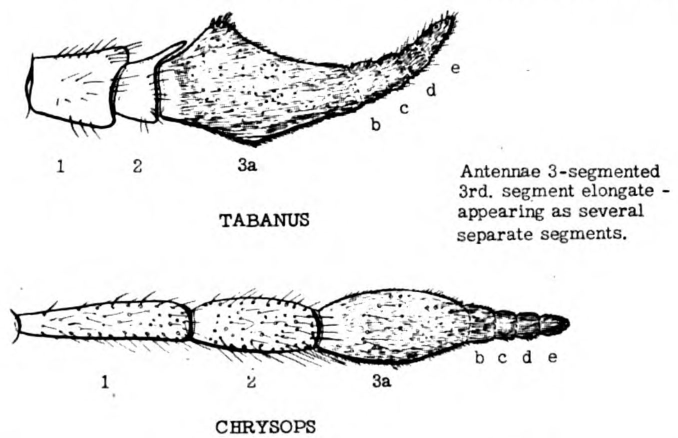


FIG. 32. Antennal characters of the suborder Brachycera.

3. **SUBORDER NEMATOCERA** - includes mosquitoes, moth flies, midges and gnats. Many members of these groups are disease vectors. All Nematocera which transmit disease have piercing mouth parts and are blood-sucking forms. Their antennae are many segmented, each segment being approximately of equal diameter throughout its length.

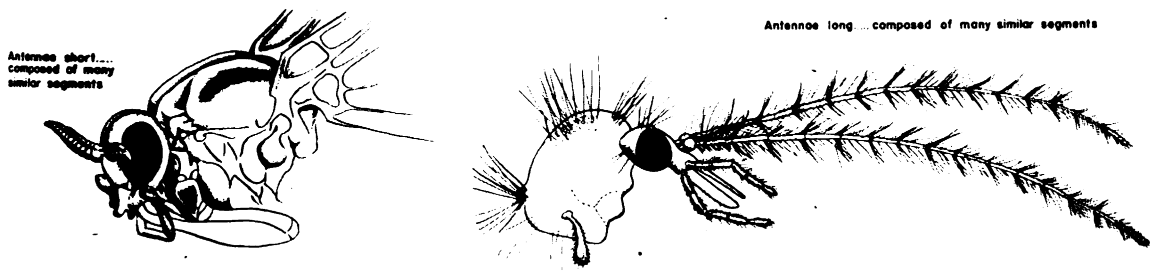


FIG. 33. Antennal characters of the suborder Nematocera.

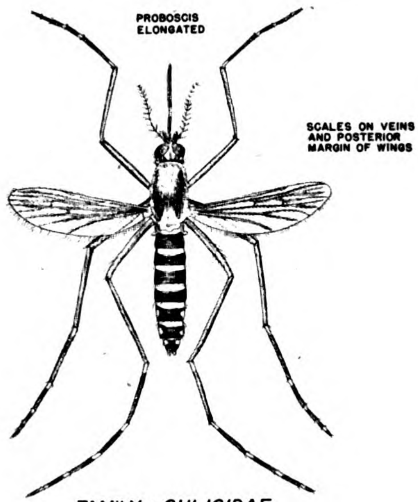
IDENTIFICATION OF MEDICALLY IMPORTANT FAMILIES OF THE ORDER DIPTERA

Included in the three suborders of the order Diptera are several families of medical interest. The suborder Athericera includes a miscellaneous group of families commonly referred to as the "muscoid flies." The medically important members of this group will be referred directly to genera to avoid unnecessarily complicating the discussion. The suborder Brachycera includes only one family of medical importance; the suborder Nematocera, four.

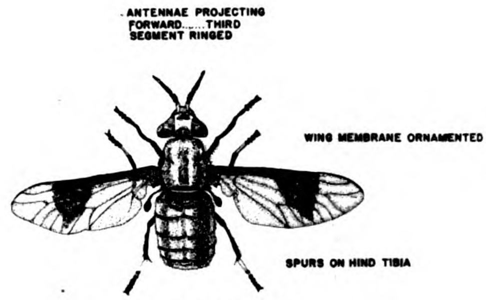
The method of identifying these families is given in the key to medically important Diptera. First, the suborders are separated out by the antennal characters; then the families, by the characters illustrated on the following plate.

PLATE XII

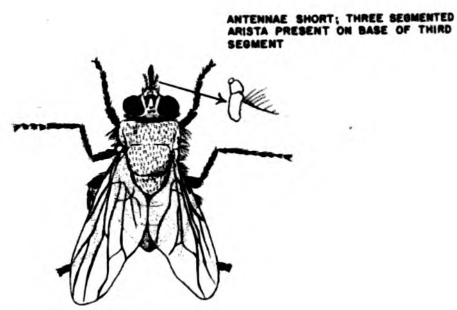
PRINCIPAL CHARACTERS FOR IDENTIFYING IMPORTANT BLOOD-SUCKING DIPTERA



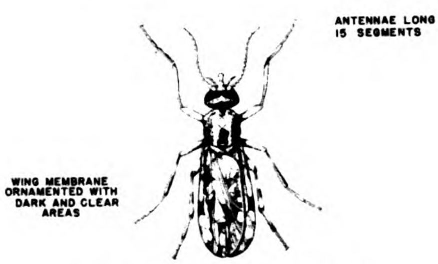
FAMILY : *CULICIDAE*
(true mosquitoes)



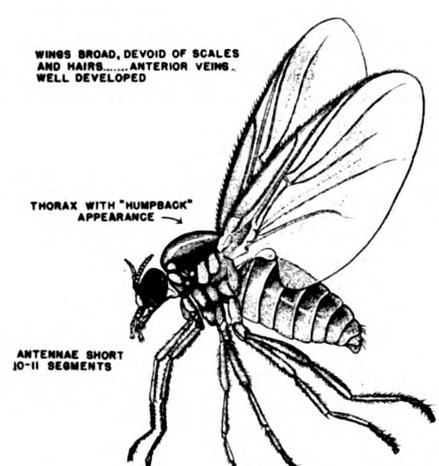
FAMILY: *TABANIDAE*
Genus: Chrysops
(deer flies, mango flies)

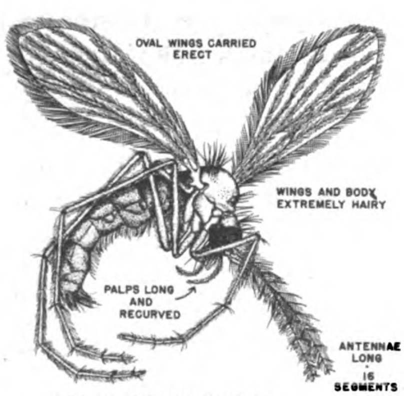


MUSCOID FLIES



FAMILY: *CERATOPOGONIDAE*
(biting midges, punkies)





FAMILY: *PSYCHODIDAE*
Genus: Phlebotomus
(sand flies, moth flies)

FAMILY: *SIMULIIDAE*
(buffalo gnats, black flies)

ORDER DIPTERA

Key To Medically Important Diptera

1. Antennae usually long, thread-like, many segmented, majority of segments usually alike; arista absent. . .(Suborder NEMATOCERA). . . . 2

   Antennae short, three-segmented. 5

2. Wings with scales; mouth parts as long as head and thorax. . . . .CULICIDAE

   Wings without scales; mouth parts short. 3

3. Wings and body extremely hairy. . . . . PSYCHODIDAE

   Wings and body sparsely haired. 4

4. Wings broad, anterior veins well developed; thorax humpbacked. . . . . .SIMULIIDAE

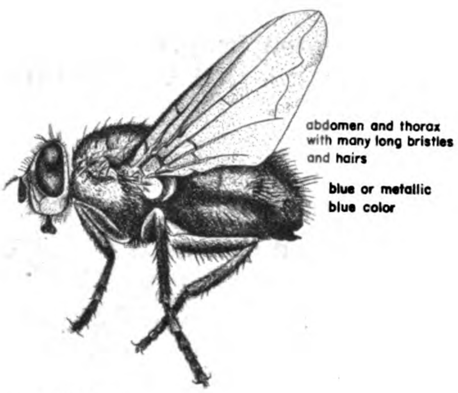
   Wings and veins of normal size, membrane ornamented with dark and light areas; thorax not humpbacked. . . CERATOPOGONIDAE

5. Arista present on base of third antennal segment. . . . . (Suborder ATHERICERA). . . . .MUSCOID FLIES

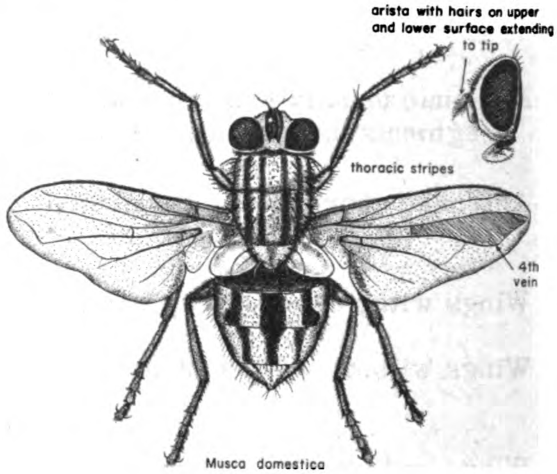
   Arista absent; antennae held horizontally erect, terminal segment elongate. . . . .(Suborder BRACHYCERA). . . . TABANIDAE

PLATE XIII

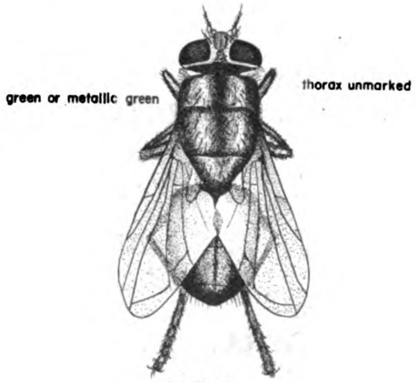
MUSCOID FLIES



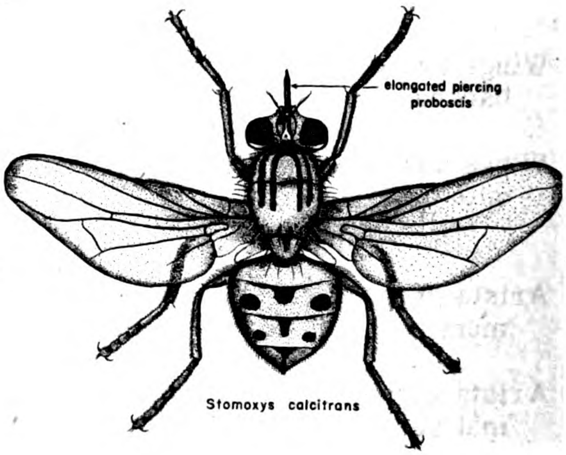
Calliphora sp.



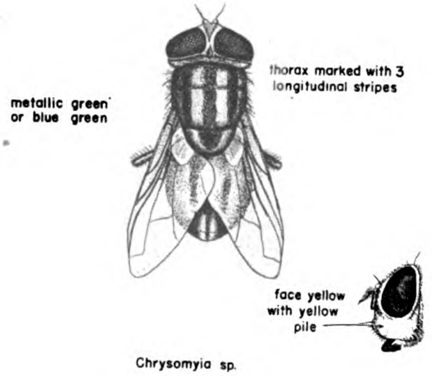
Musca domestica



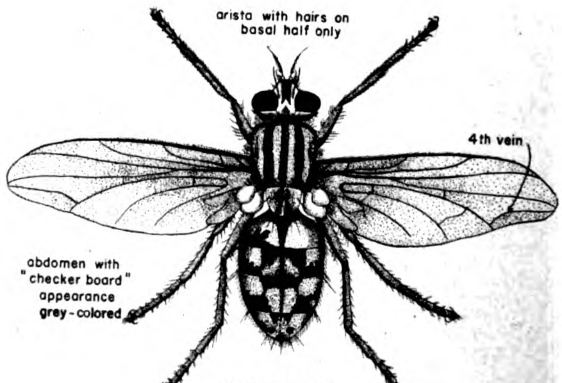
Lucilia sp.



Stomoxys calcitrans



Chrysomyia sp.



Sarcophaga sp.

ORDER DIPTERA

SUBORDER ATHERICERA
(muscoid flies)

RELATION TO MAN: Only one genus, Glossina, is known to be a true biological vector of a human disease, African sleeping sickness. The other genera are chiefly important as mechanical carriers of such diseases as typhoid fever, cholera, and bacillary and amoebic dysentery. In a large number of genera the larvae may be internal parasites of man, producing a condition known as myiasis. Because of the great diversity in form and medical importance, we have divided the various genera of the muscoid flies into three small groups:

1. The skin-piercing group includes the genera Glossina, Stomoxys, and Siphona (= Haematobia). These blood-sucking flies have piercing mouth parts, the proboscis projecting well beyond the head. They are true or potential vectors of disease and usually vicious biters.

2. The mechanical contaminators include the flies of the genera Musca, Fannia, Hippelates, Sarcophaga, Calliphora, and Lucilia. These flies have fleshy, lapping, non-piercing mouth parts, and their living and feeding habits are such as to enable them to innoculate man mechanically, through his food or mucous membranes, with the bacterial and protozoal filth of feces, disease exudates, and decomposing organic matter.

3. The flies whose larvae are occasional or habitual internal parasites of man include species of the genera, Musca, Fannia, Lucilia, Cochliomyia, Chrysomyia, Sarcophaga, Cordylobia, Auchmeromyia, Dermatobia, and Calliphora. These larvae invade the intestines, the nasal openings and associated sinuses, and the subdermal and muscular tissues of man. Such an infestation of tissues or body-spaces by flies is referred to as myiasis. The adults of these flies, with rare exceptions, have non-piercing mouth parts.

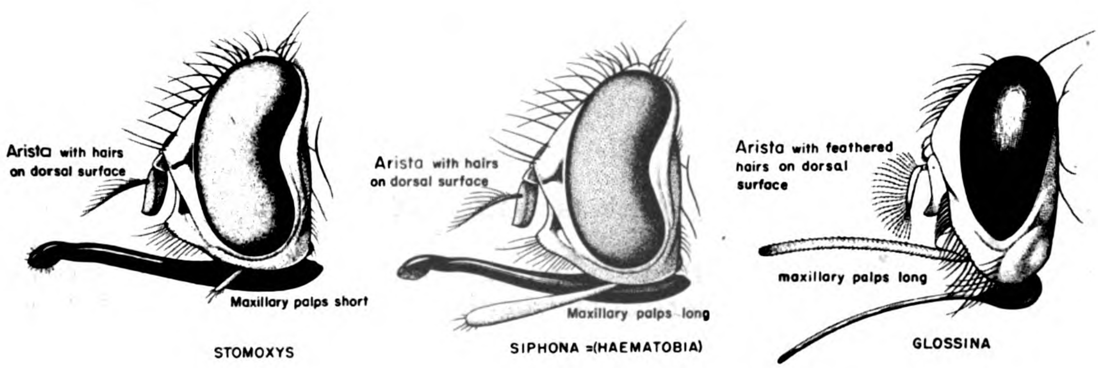


FIG. 34. Heads of important piercing muscoid flies.

SUBORDER ATHERICERA

GROUP I. THE SKIN-PIERCING MUSCOID FLIES

Key To The Important Skin-Piercing Muscoid Flies

1. Palpi short. . . . . *Stomoxys*
   Palpi long. 2

2. Hairs on dorsal surface of arista unbranched. . . . . . *Siphona* (= *Haematobia*)
   Hairs on dorsal surface of arista branched and feather-like. . . . . . *Glossina*

Glossina - the tsetse fly

GENERAL CHARACTERISTICS: The tsetse fly may be distinguished from all other flies by its slender, forward-projecting proboscis; its spiny, long, slender palpi;the feathered hairs on the dorsal side of the antennal arista; and the characteristic "meat cleaver" cell in the wing. There are about twenty-five species of tsetse flies, of which only three are of primary importance in human disease. Tsetse flies occur only in Africa, except for one species in the southwest corner of Arabia.

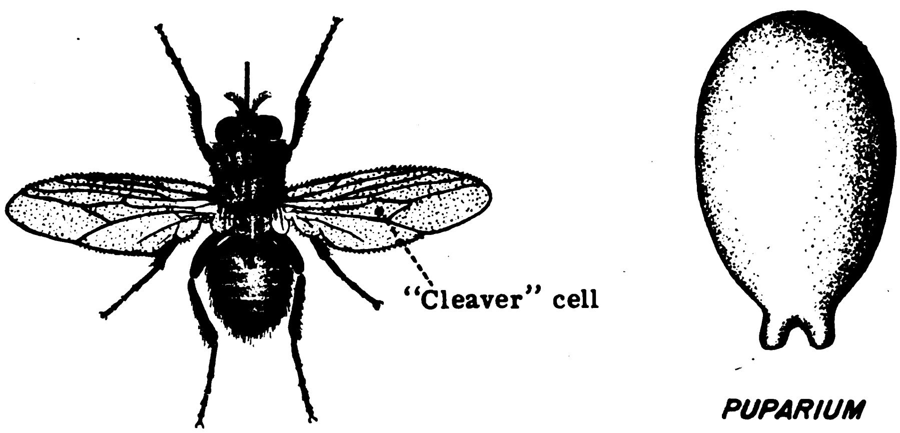


FIG. 35. *Glossina.* Adult tsetse fly and puparium.

RELATION TO MAN: Among the skin-piercing flies, the tsetses rank second only to the mosquitoes as transmitters of human disease. They are the esential biological vectors of Gambian and Rhodesian sleeping sicknesses, which are caused by trypanosomes. Sleeping sickness is widely distributed throughout Central Africa, where it is estimated to have killed a half million natives in the ten-year period beginning in 1896.

SKIN-PIERCING MUSCOID FLIES

The trypanosomes undergo a regular cyclo-propagative development in _Glossina._ After three to four weeks, they are ejected in the saliva of the fly, the fly remaining infective for at least three months thereafter. Numerous species of wild mammals harbor the trypanosomes in nature, forming a reservoir of the disease.

LIFE CYCLE AND HABITS: The female tsetse fly nourishes her young on "intrauterine milk glands" and produces one full-grown larva each ten or twelve days during her lifetime of four or more months. The larvae burrow into coarse sand or other loose soil and pupate within an hour after birth. The pupae, which have very characteristic posterior lobes, require about three weeks for their development.

The flies are restricted to certain characteristic "fly-belts," the type of area infested varying with the species. Of the three species of medical importance, the preferred food of one is reptile blood; of the other two, the blood of game animals. The flies are diurnal feeders. They prefer dark or brown skins to light ones and have been caught in large numbers on black cloths smeared with "tanglefoot." Both sexes feed on blood.

CONTROL: Because of the diversity of habits among tsetse flies and the practical absence of a free-living larval form, the tsetse flies are difficult to control. Among the possible modes of attack suggested are the following: the use of fly-traps for the adults, the introduction of natural enemies, modification of cover, control of game animals, and the establishment of fly-barriers by setting up clearings or thickets, according to the species involved.

Stomoxys - the stable fly or dog fly

Although _Stomoxys_ has been frequently used in experimental transmission, there is no conclusive evidence that it is a _natural_ vector of human disease. However, because of its blood-sucking habits, it will always be regarded as a potential disease vector.

Stomoxys resembles the house fly rather closely and is sometimes referred to as the "biting house fly," but it can readily be distinguished by its slender piercing proboscis.

Siphona (= _Haematobia_) - the horn fly

The horn fly is a serious pest of cattle, but rarely attacks man. Because of its blood-sucking habits, it will always be regarded with suspicion as far as disease transmission is concerned. It closely resembles the common house fly, but is only about half its size.

SUBORDER ATHERICERA

Key To The Non-Piercing Muscoid Flies

1. Small dark flies; base of abdomen and legs yellow; hind tibiae with prominent curved apical spur; antennal arista bare. . . . . Hippelates

   Medium-sized or large flies. 2

2. Grey or dull-colored flies. 3

   Blue, metallic green, or blue-green flies. 5

3. Bend of fourth vein acute, joining margin of the wing close to the third vein; arista with hairs. 4

   Bend of fourth vein absent, reaching wing margin far below third vein; arista bare. . . . . Fannia

4. Large, grey colored flies; abdomen with a "checker-board" appearance; arista with hairs only on the basal half. . . . . . . Sarcophaga

   Medium-sized greyish-black flies; abdomen without "checker-board" appearance; thorax marked with two or four dark longitudinal stripes; arista with hairs on upper and lower surfaces extending to the tip. . . . . .Musca

5. Large-sized blue flies, with white sheen over body; many long bristles and hairs on thorax and abdomen. . . . . .Calliphora

   Medium-sized, metallic green or blue-green flies; short bristles on thorax and abdomen. 6

6. Thorax marked with three longitudinal stripes; face yellow with yellow pile. . . . . Cochliomyia and Chrysomyia

   Thorax unmarked; face without yellow pile. . . . . Lucilia

SUBORDER ATHERICERA

GROUP 2 - THE CONTAMINATING MUSCOID FLIES

Musca domestica - the common house fly

GENERAL CHARACTERISTICS: In the house fly, there are four dark stripes on the thorax, and a dark central area on the abdomen. The mouth parts are not sharply pointed as in the stable fly (*Stomoxys*) and are of the type illustrated in Plate XI, figure D. The pad-shaped tip on the non-piercing, sponging mouth parts is a convenient mechanism for mechanical transfer of pathogenic organisms from infected material to healthy individuals. The common latrine fly (*Fannia scalaris*) is often mistaken for the house fly, but an examination of the wings and antennae will differentiate the two.

RELATION TO MAN: The house fly and many of its relatives are common agents in the mechanical transmission of certain infections which are often grouped under the term, "fly-borne diseases." The mouth parts, the numerous body spines, and the sticky pads on the feet have been found to carry a large number of different pathogens causing human disease. Some of these pathogens may pass unaltered through the digestive tract and may remain viable in the feces or "fly specks." Among the pathogens carried mechanically by the house fly are included those causing typhoid fever, cholera, bacillary and amebic dysentery, tuberculosis, anthrax, leprosy, bubonic plague, yaws, conjunctivitis, trachoma, erysipelas, gonorrhea, septicaemia, abscesses, and gangrene. Flies may also carry the eggs of certain parasitic worms, such as hookworm, whipworm, and other roundworms.

LIFE CYCLE AND HABITS: Egg. The eggs of the house fly are laid in masses of about 75 - 150, a single female being able to lay as many as twenty-one such batches in the month after emergence. Excrement, especially that of horses, is a favorite breeding material. Cattle, hog, chicken, and human feces are also used by flies for breeding. The fact that they breed readily in human excrement makes them especially dangerous as disease carriers. Other suitable materials include garbage, kitchen refuse, and other decomposing vegetable and animal matter.

Larva. Hatching takes place in about twenty hours under warm summer conditions, and the slender, white, legless maggot completes its development in about five days.

Pupa. After the maggot attains its full growth, it migrates to drier parts of its habitat and changes to a pupa within the smooth, dark brown, barrel-shaped puparium, a covering formed by the last larval skin which is not shed. The pupal stage requires about four days, making a total of about ten days from egg to adult insect.

Adult. Successive broods of flies follow each other throughout the summer, resulting in a great increase towards autumn. Their reproductive ability can best be illustrated by the following: A pair of flies at the beginning of the breeding season may be the progenitors, if all were to live, of 191,000,000,000,000,000,000

offspring by August. Allowing one-eighth of a cubic inch to each fly, this number would cover the earth to a depth of forty-seven feet!

A very practical problem in the relation of house flies to disease is the extent to which they may scatter from their breeding places. As a rule, most flies will not travel more than a quarter of a mile in thickly settled areas, but a maximum distance of thirteen miles has been reported. Some house flies have been recovered six miles from the point of their release in less than twenty-four hours. Thus, their migratory habits are sometimes marked.

The ominivorous habits of the house fly should be well known to everyone. From the disease viewpoint, it should be emphasized that from feeding on excrement, sputum, open sores, or putrefying matter, the flies may quickly pass to food or milk, to healthy mucous membranes, or to uncontaminated wounds. It is these filthy habits that make this fly and related forms such dangerous mechanical vectors of disease.

The method of feeding has an important bearing on the house fly's ability to transmit disease organisms. When feeding, the fly frequently moistens substances with a "vomit drop" which is regurgitated from the crop. This vomit drop dissolves solid materials to be used as food, and most of the material is sucked up again. The vomit drop may be teeming with typhoid and cholera bacilli, or with the organisms causing amebic or bacillary dysentery, which are thus transferred to food and milk. In the same manner, the spirochaetes of yaws may be transferred by flies feeding on the yaws ulcer and then on scratches or skin abrasions of healthy individuals. The causative agent of trachoma may be spread by flies feeding on infective matter in the eyes of patients or on soiled bandages.

<u>CONTROL:</u> House fly control measures are mainly directed toward the suppression of fly breeding, but also include measures against the adults, as well as protective measures designed to exclude flies and prevent their contamination of food.

Since manure, particularly that of horses and hogs, constitutes one of the principal breeding places, proper disposal is of great importance. Manure can be sprayed with a DDT water emulsion in concentrations as low as 0.1 per cent to kill any fly larvae which may develop. Fly breeding in human excreta is particularly dangerous, hence latrines, wherever possible, should be carefully fly-proofed. In temporary camps, enforcing the use of trench latrines and the prompt covering of feces are extremely important. With more permanent latrines, daily policing, spraying with crude oil, or burning-out should be practiced.

Neglected garbage furnishes an excellent breeding material. Garbage cans should be available, kept tightly covered, and thoroughly cleaned when empty. Garbage can be burned, buried, or disposed of at sea some distance offshore.

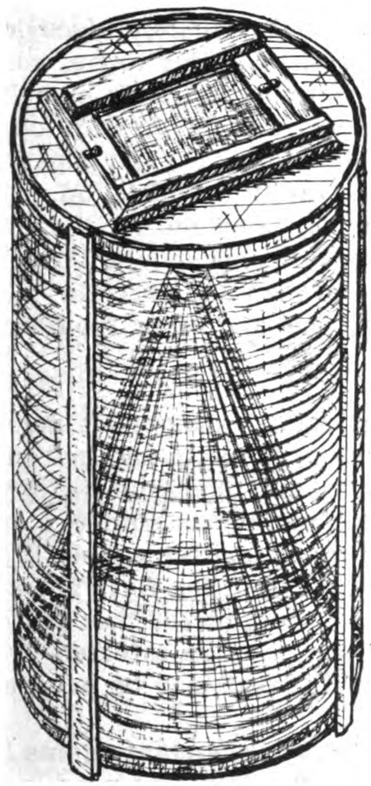


FIG. 36. A well constructed fly trap.

Screening, fly traps, sprays, poisons, fly papers, and fly swatters are all important measures against adults. Traps should be placed near galleys, mess halls, garbage houses, and latrines. A simple, effective poison can be made by adding three teaspoonfuls of commercial formalin to one pint of milk or water with a little brown sugar added. This can be exposed on a small saucer lined with blotting paper, or a feeder made by inverting a glass full of the solution over a similarly lined saucer with a piece of match stick under the rim to keep the paper moistened with the poison.

The most remarkable new development in fly control is the use of DDT against the adults. When a five per cent mixture of DDT in kerosene or in an emulsion is sprayed on any surface, the DDT remains as an almost invisible deposit after the liquid has evaporated. This acts as a residual contact insecticide against any flies which may walk over such treated surfaces and continues to kill flies for at least <u>three months</u> after its initial application. DDT can be used very effectively on walls, ceilings, and screens in galleys, mess halls, garbage houses, garbage racks, barracks, latrines, stables, barns, wherever flies are accustomed to light.

<u>Hippelates</u> - the eye gnat

<u>GENERAL CHARACTERISTICS:</u> <u>Hippelates</u> is small in size and usually has a dark body with the underside of the abdomen and legs yellow. The antennae are characteristic, the third segment being almost globular and the arista bare. There is a distinct, curved, shining, black, apical or subapical spine on the hind tibia.

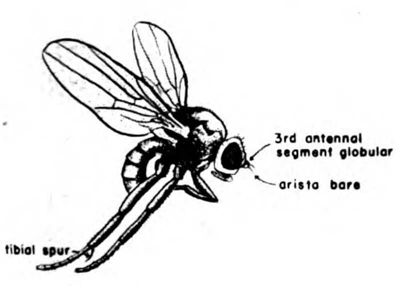


FIG. 37. <u>Hippelates.</u>

<u>RELATION TO MAN:</u> The eye gnats have been incriminated as carriers of such diseases as yaws and of infectious conjunctivitis or "pink eye." These small flies show extraordinary persistence in returning to feed on lachrymal secretions, even though brushed away continuously. This habit has given them the name of "eye gnats" or "eye flies." They do not bite, but the spines on the labellum apparently act as a rasping instrument capable of producing multiple lesions which assist in invasion of pathogenic organisms.

CONTAMINATING MUSCOID FLIES

LIFE CYCLE AND HABITS: The eggs are deposited on a wide range of decaying organic matter including excrement, provided the material is rather loose, mixed with soil, and well aerated. Evidently, they will not develop naturally in closely compacted soil or putrid material, or in excrement unless it is mixed with loose earth. The larvae require about eleven days for their development, and pupation takes place close to the surface of the material in which the larvae develop. The pupal stage lasts about six days, making a total of about three weeks for the completion of the life cycle. Although the adults do not have piercing mouth parts, they are habitually attracted to the skin and natural orifices of man and animals. Here they lap up lachrymal secretions, sebaceous secretions, pus and blood from wound exudates or from scratches and insect bites.

The habits of these insects thus render them particularly dangerous mechanical carriers of eye infections and of various diseases of the skin and mucous membranes. Evidence is available to show that, in Jamaica, Hippelates pallipes may be an actual carrier of the organism causing yaws. Enormous numbers of flies have been observed on the ulcerative lesions; and the causative agent, Treponema pertenue, has been found in the anterior gut and stomach of the fly. The spirochaetes survive only about seven hours in the gut, and it is suggested that the yaws infection is transmitted to another individual by regurgitation of an infected "vomit drop" when the fly feeds on any skin abrasion or ulceration that may be present.

It has been reported that Hippelates flies are probably important agents in the transmission of catarrhal conjunctivitis or "pink eye," since they are readily attracted by the resulting lachrymal secretions.

CONTROL: Control of Hippelates is difficult, involving a combination of measures, such as trapping, using freshly chopped liver as bait; sanitation, removal of garbage, manure piles, refuse heaps, and decaying vegetable matter; and occasionally certain agricultural methods, such as light disking.

Miscellaneous Mechanical Contaminators

In addition to the well-known house fly and eye gnat discussed above, a number of other muscoid flies may also play a role as mechanical contaminators. In the tropics, and especially in Africa and in certain of the South Pacific islands, closely related species of Musca, similar in appearance and habits to the common house fly, may be important disseminators of intestinal diseases and of yaws. Other genera may also be involved, and some of the more common forms are listed below:

Fannia - the latrine fly
Lucilia - the green bottle fly
Sarcophaga - the gray flesh fly
Calliphora - the blue bottle fly

SUBORDER ATHERICERA

GROUP 3 - THE MYIASIS-PRODUCING MUSCOID FLIES

RELATION TO MAN: Myiasis is a term applied to the disease produced by fly maggots or larvae when they live parasitically in the organs and tissues of man or animals. Clinically, myiases may be classified according to the part of the body invaded. Thus, when the invasion involves the intestinal tract, it is referred to as "intestinal myiasis"; when it involves the skin, "cutaneous myiasis." Other types are designated urinary, ophthalmic, auricular, traumatic, or nasal myiasis.

The myiasis-producing flies may be grouped according to the degree of insistence displayed by the adult flies in selecting living tissues in which to deposit their young.

1. Obligatory Parasites: These larvae invade and develop only in living tissues.

Examples: (a) Chrysomyia bezziana, the commonest cause of human myiasis in India.

(b) Dermatobia, the tropical warble fly, a cause of cutaneous myiasis in man and other warm-blooded animals.

(c) Hypoderma, the cattle-bot fly, the occasional cause of "larva migrans" in the skin of man.

(d) Cochliomyia americana (= hominovorax) the primary screw worm, a not infrequent cause of traumatic and nasal myiasis in man.

2. Facultative Parasites: These maggots normally live in decomposing matter, but the adults may occasionally lay eggs in living tissues, being attracted by foul discharges and blood.

Examples: (a) Cochliomyia macellaria, the secondary screw worm.

(b) Lucilia, the green bottle fly.

(c) Sarcophaga, the gray flesh fly.

3. Accidental Parasites: The eggs or larvae of these flies are sometimes swallowed, usually in food or drink. Under such circumstances, the maggots may develop in the intestine, but this development is accidental and not a part of the normal life cycle or the result of any choice on the part of the fly.

Examples: Species of Calliphora, Sarcophaga, Musca, Fannia, Eristalis, and Stomoxys.

Note that although the adults of these forms belong almost entirely to the non-piercing muscoids, one genus, Stomoxys, of the piercing group also has larvae which may cause intestinal myiasis. For identification of the adults, see page 64 for those species discussed under the non-piercing muscoid flies. In this section only the larvae which cause myiasis are described.

MYIASIS-PRODUCING MUSCOID FLIES

<u>IDENTIFICATION OF MYIASIS-PRODUCING FLY LARVAE:</u> Maggots, the larvae of the muscoid Diptera, are footless, wormlike, and more or less cylindrical. They usually taper anteriorly and are broad and truncate posteriorly, with eleven or twelve distinct segments. At the blunt or posterior end is a pair of <u>stigmal plates.</u> Each plate covers the opening into a breathing tube, or trachea, and is characteristically shaped and perforated to allow the passage of gases. The shape, sculpturing, and position of the stigmal plates are characters used in the identification of maggots.

Detailed preparation is not necessary for an examination of the stigmal plates and spiracles. It is sufficient merely to remove a thin slice at the posterior end of the larva and examine it under the low power of the microscope. The following key and its accompanying chart will serve to identify the more common fly larvae concerned in myiasis.

<u>Key To The Important Myiasis-Producing Larvae</u>

1. Body with spinous or fleshy processes laterally and dorsally or terminally. . . . . <u>Fannia</u>
   Body without spinous or fleshy processes. 2

2. Body with long tail-like process. . . . . <u>Eristalis</u>
   Body without such structure. 3

3. Body robust, ovate, or pyriform. 4
   Body truncate, broadly rounded at one end and tapering at the other (head) . . 5

4. Larva flask-shaped, heavily spined, posterior spiracular plate with three distinct slits. . . . . <u>Dermatobia</u>
   Larva grub-like, heavily spined, posterior spiracular plate with many fine openings. . . . . <u>Hypoderma</u>

5. Posterior spiracular plates with button area well chitinized and the ring complete. 6
   Posterior spiracular plates with button area very slightly chitinized and ring incomplete. . . . . . . <u>Cochliomyia</u>, <u>Sarcophaga</u>, <u>Chrysomyia</u>

6. Button area a part of the ring, slits nearly straight. . . . . <u>Calliphora</u>, <u>Lucilia</u>
   Button area within the ring. 7

7. Posterior spiracular plates D-shaped, each slit thrown into several loops. . . . . <u>Musca</u>
   Posterior spiracular plates triangular, with rounded corners. 8

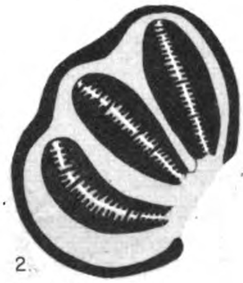
8. Spiracular slits S-shaped, button indistinct, centrally placed. . . . . <u>Stomoxys</u>
   Spiracular slits straight, button near edge, well within the ring. . . . . <u>Auchmeromyia</u>

PLATE XIV

KEY CHARACTERS OF MYIASIS-PRODUCING FLY LARVAE

MATURE LARVA OF A MUSCOID FLY

1. *Sarcophaga sp.*



2. *Cochliomyia macellaria*

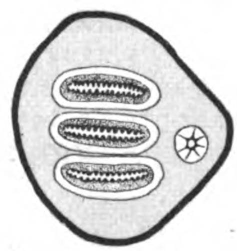
3. *Lucilia sericata*

4. *Calliphora erythrocephala*

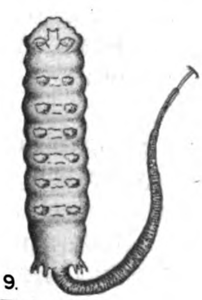
5. *Musca domestica*

6. *Stomoxys calcitrans*

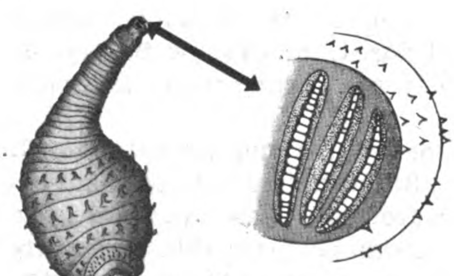
7. *Hypoderma lineata*



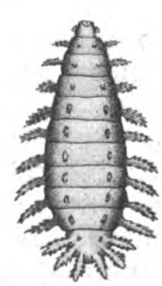
8. *Auchmeromyia luteola*



9. *Eristalis tenax*



10. *Dermatobia hominis*



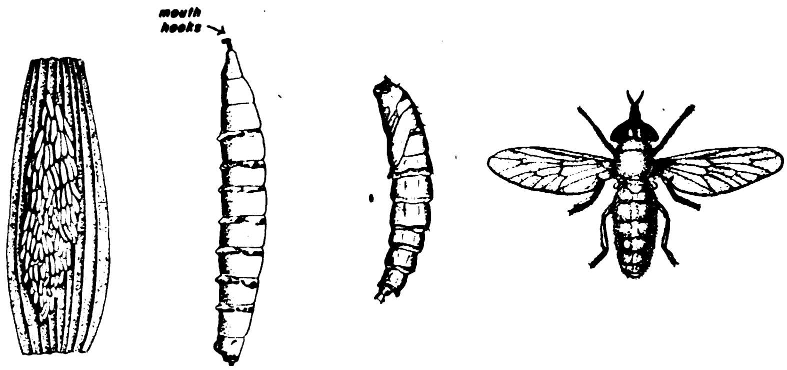
11. *Fannia scalaris*

ORDER DIPTERA

SUBORDER BRACHYCERA

FAMILY TABANIDAE
(horse flies, deer flies, mango flies)

GENERAL CHARACTERISTICS: Members of the family TABANIDAE are large sturdy flies with large hemispherical heads and very large eyes. The short antennae are characteristically extended horizontally and are composed of three segments, although the terminal segment is often annulated so distinctly as to give the appearance of six or seven segments. The proboscis is short, with broad, cutting blades. Only the females suck blood. The males feed on the nectar of flowers and on plant juices.



A B C D

FIG. 38. Life cycle of a tabanid fly:
A. Eggs. B. Larva. C. Pupa. D. Adult.

LIFE CYCLE AND HABITS: Typically, the eggs are deposited in masses on water plants or grasses growing in marshy or wet ground. Within a week the eggs begin to hatch and the cylindrical larvae drop to the water, or make their way to damp earth, and live an aquatic carnivorous life, feeding on worms, snails, or insect larvae. Under optimum conditions, the larval stage lasts for several months or a year. The pupal period is of short duration, ranging from one to three weeks. The adults are usually quite large. They are strong fliers and persistent biters.

CONTROL: The habits of these flies and the nature of their breeding places make control measures difficult. Since the eggs are usually laid on vegetation overhanging water, an oiling of the water to act as a contact poison to the larvae as they emerge from the egg is recommended for this immature stage. Often, the adults congregate in great numbers in the neighborhood of damp places and lower themselves to the surface of pools to drink, actually touching the water with their bodies. It is possible to kill large numbers of such adults by applying a liberal amount of kerosene to the pool of water. Pools treated in such a manner apparently attract the tabanids from over a considerable adjacent area.

ORDER DIPTERA

SUBORDER NEMATOCERA

FAMILY PSYCHODIDAE
(moth flies, sand flies, owl flies)

GENERAL CHARACTERISTICS: The members of this family are minute, dark-colored insects whose bodies and wings are densely covered with hairs, thereby giving them the appearance of small moths, hence the name "moth flies." Scales may be found on various parts of the body, but never on the wings. The wings, in addition to being densely covered with hairs, are short and broad, and characterized by the paucity of branching of the veins. The antennae are 12-16 segmented and usually fairly long.

FIG. 39. Head and mouth parts of *Phlebotomus*.

The Psychodidae are generally divided into two types, the blood-sucking and the non-blood-sucking. Since only the blood-sucking types are of medical importance, only members of the blood-sucking genus *Phlebotomus* (sometimes spelled *Flebotomus*) will be considered here.

RELATION TO MAN: The principal diseases transmitted by members of the genus *Phlebotomus* are: pappataci fever, leishmaniasis (kala-azar and oriental sore), and verruga peruana. In addition to the role these sand flies play in the transmission of disease, they are vicious biters. Only the females feed on blood.

LIFE CYCLE AND HABITS: Immature Stages. The eggs of *Phlebotomus*, laid in batches of about fifty, are deposited in dark, moist crevices of rocks or concrete walls, in damp cracks in shaded soil, caves, embankments, or other places where there is an abundance of organic matter and sufficient moisture for their development. In six to nine days the eggs hatch into caterpillar-like, mandibulate larvae which feed on any available organic debris. In the course of about one month, the larvae undergo three molts and transform into naked pupae. The pupal stage lasts about ten days. Under favorable conditions, a complete cycle from egg to adult requires about six to eight weeks.

Adult Stage. The adults are very minute and can easily crawl through the meshes of the ordinary mosquito net. Their bites are very annoying and in some species cause an irritation which seems quite out of proportion to the size of the insect. They seldom bite except in hours of darkness, and in some places seek food for only an hour or so after sundown. During the day they hide in dark corners and cellars or crevices of rocks. Their power of flight is very limited, and their breeding places are nearly always within a few hundred feet of their feeding places. The adults suck blood of almost any warm blooded animal and thus are quite independent of man as a host.

FAMILY PSYCHODIDAE

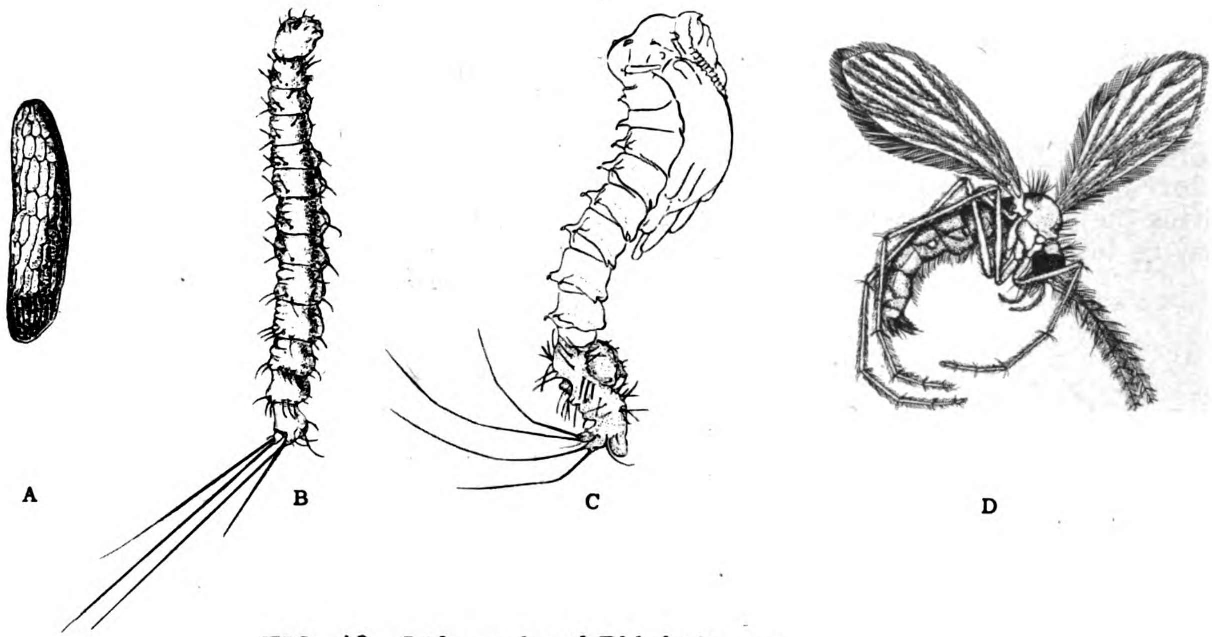


FIG. 40. Life cycle of Phlebotomus.
A. Egg. B. Larva. C. Pupa. D. Adult.

CONTROL: The bites of these flies can often be prevented most simply by avoiding their habitats. Because of the minute size of the adult and the numerous places where they may hide out during the daylight hours, the flies are difficult to kill by direct measures. Breeding places may be abolished by destroying old foundations and removing rocks or piles of stones; cementing up cracks and crevices in stone walls and exposing breeding areas to direct sunlight. Since the adults avoid winds, an effective measure is the use of electric fans so placed as to produce a current of air in the direction of the windows of sleeping quarters. Repellents are also used as a precaution against the adults.

FAMILY CERATOPOGONIDAE
(biting midges, punkies, no-see-ums, sand flies)

GENERAL CHARACTERISTICS: The members of the family Ceratopogonidae are very small, slender, blood-sucking gnats. Locally, these midges occur in sufficient numbers to make them almost intolerable. They bite chiefly in the evening and very early in the morning. In some species the bite is very painful and extremely irritating, causing nodular, inflamed swellings that itch persistently for several days or even weeks. The insects work themselves beneath the clothing and apparently prefer to bite at some point where their progress is impeded, such as around the hat band, at the belt line, or at the shoe tops.

RELATION TO MAN: The great majority of the species which attack man belong to

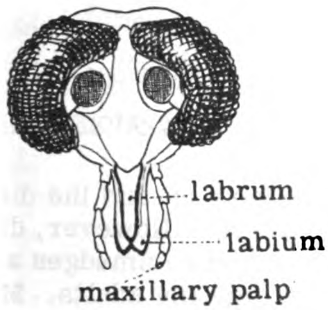


FIG. 41. Head and mouth parts of Culicoides.

the genus Culicoides. These blood-sucking midges have been accused of transmitting South American dermal leishmaniasis and have been proved to serve as intermediate hosts of two filarial worms, considered to be non-pathogenic to man, Acanthocheilonema perstans and Mansonella ozzardi.

LIFE CYCLE AND HABITS: Immature Stages. The eggs are laid in a variety of situations, but mainly in water or water-saturated sand or soil. The larvae are small, legless, wormlike creatures, with a small brown head and twelve body segments. The slender brown pupae are provided with two short breathing tubes on the thorax. They float nearly motionless in a vertical position, the respiratory tubes in contact with the surface film. The entire life cycle requires from six to twelve months.

Adult Stage. The adults are all small and seldom exceed 2-3 mm. in length. The wings are more or less covered with erect setae or hairs and, in many species, variously marked with iridescent blotches. The antennae have fourteen segments and the palpi usually have five.

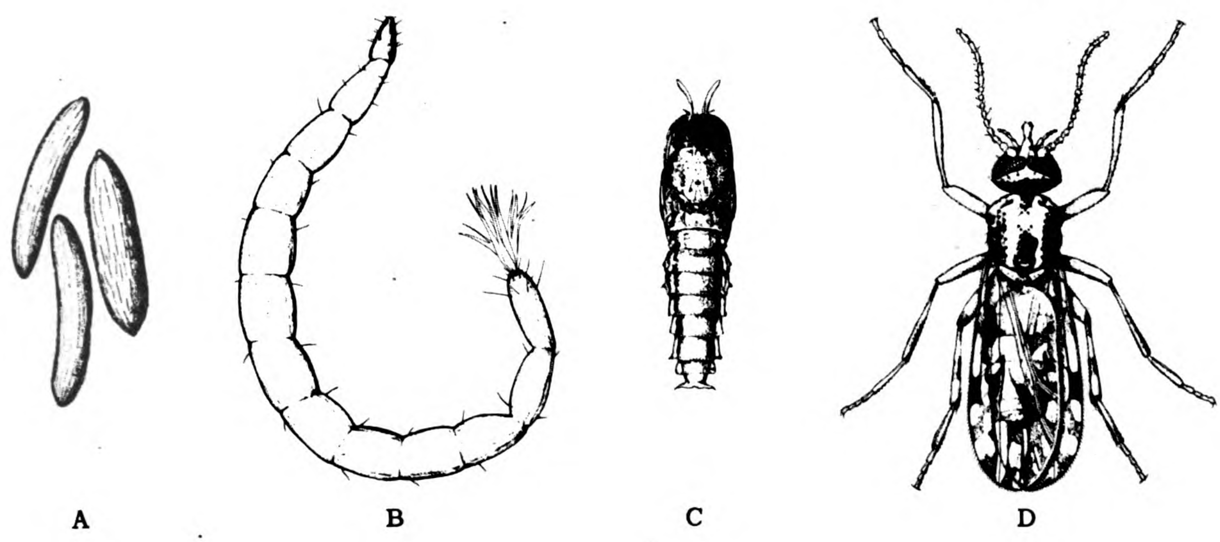


FIG. 42. Life cycle of Culicoides.
A. Egg. B. Larva. C. Pupa. D. Adult.

FAMILY CERATOPOGONIDAE

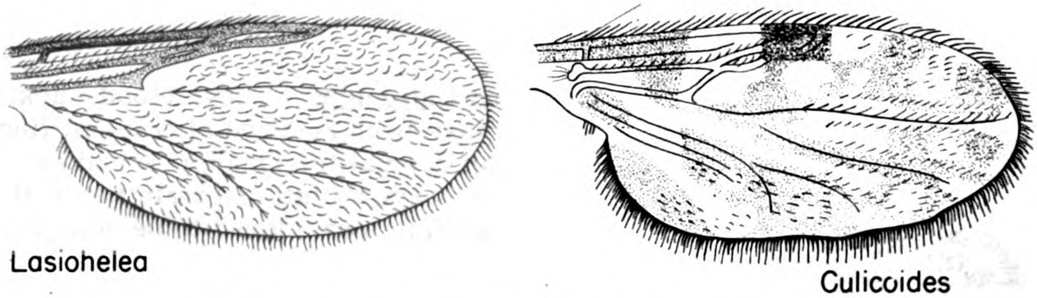


FIG. 43. Wings of two blood-sucking genera of the family Ceratopogonidae.

CONTROL: Until more is known of the breeding places of the pest and the disease-carrying species, control by means of larvicides is not feasible. However, drainage of marshy areas has been pursued with some success. Smoke smudges and other repellents can often be used with advantage to discourage the adults. Mosquito netting and screens should be sprayed with repellents to prevent the adults gaining access to sleeping quarters, or sprayed with five per cent DDT in kerosene as in house fly control. A mixture of one part pyrethrum extract concentrate (20-1) and twenty parts lubricating oil (S.A.E. 5) applied by means of a brush or rag to window screens is reported to exclude the adults for twenty-four to forty-eight hours.

FAMILY SIMULIIDAE
(black flies, buffalo gnats)

GENERAL CHARACTERISTICS: The Simuliidae are small (1-5 mm. long), dark, chunky flies with piercing-sucking mouth parts. Distinguishing characteristics are: the hump-backed appearance and the relatively short, broad, clear wings in which only the anterior veins are well developed. The antennae are many jointed (10-11), but are short with bead-like segments instead of being long and filamentous as in other members of the Nematocera.

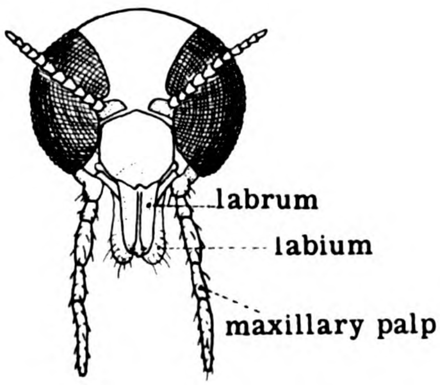


FIG. 44. Head and mouth parts of Simulium.

RELATION TO MAN: Only one genus of this family has been found to transmit disease. Species of Simulium are intermediate hosts for the filarial worm, Onchocerca volvulus, the organism causing onchocerciasis in certain parts of Africa, Mexico, and Central America. Black flies are vicious and persistent biters. They attack both human beings and domestic animals, sometimes killing livestock. As in mosquitoes, only the females are able to pierce the skin.

LIFE CYCLE AND HABITS: Immature Stages. The small, glistening yellow eggs are laid in masses of about 500 on stones and vegetation in swiftly running streams. They hatch in five to thirty days and the larvae attach themselves to rocks or sticks

in the water. After about a month the larvae spin cocoons and pupate, fastened to the rocks. The entire life cycle usually requires from ten to thirteen weeks, but Simulium may overwinter either in the egg or larval stage.

Adult Stage. Black flies usually appear in large numbers. They make little noise in flight and alight on the skin and bite quickly. They are active mainly during the daylight hours and seldom enter houses. The adults are short-lived.

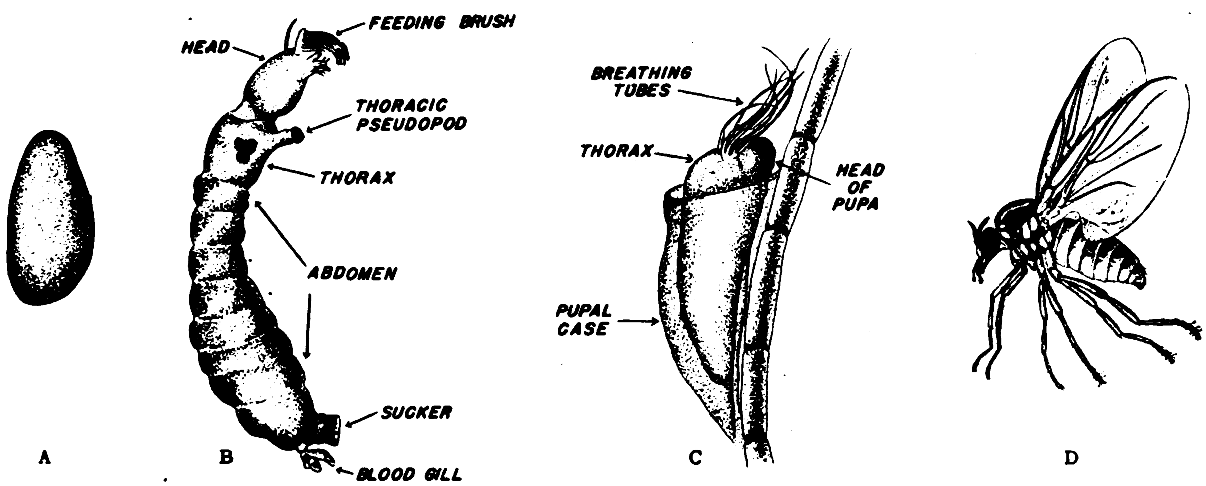
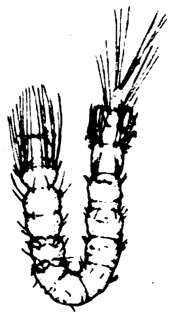


FIG. 45. Life cycle of Simulium.
A. Egg. B. Larva. C. Pupa. D. Adult.

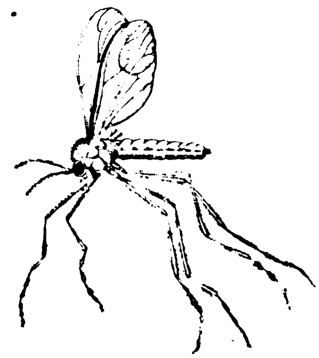
CONTROL: Destruction of the larvae is difficult. Clearing streams of logs, sticks, stones, and other obstructions helps, as does sweeping the larvae from the rocks with a stiff broom. Miscible coal tar creosote oil poured into a stream for two to four minutes in sufficient quantity to give the water a milky-white appearance will kill the larvae. Damming a stream in such a way as to produce a series of quiet pools connected by short waterfalls contracts the breeding area and limits the number of black flies produced. Protection out-of-doors must be sought through the use of smudges and other repellents and in the complete coverage of the skin by heavy clothing. The use of the standard GI repellent has proved very effective against black flies.

PLATE XV

LIFE CYCLES OF NON-BITING MOSQUITOES

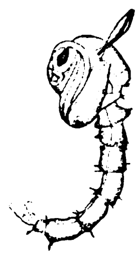

Larva

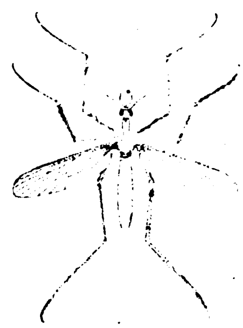

Pupa


Adult

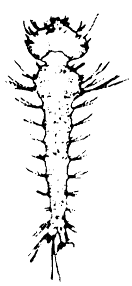
Subfamily Dixinae: Dixa

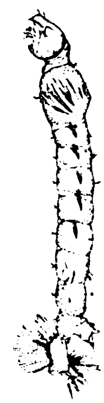

Larva

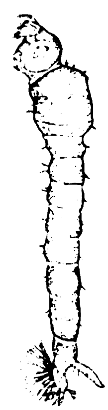

Pupa


Adult

Subfamily Chaoborinae: Chaoborus


Corethrella


Eucorethra


Mochlonyx

Other Chaoborid Larvae

SUBORDER NEMATOCERA

FAMILY CULICIDAE
(mosquitoes)

GENERAL CHARACTERISTICS: All mosquitoes are included in the family Culicidae, a group of Nematocerous flies in which the third vein of the wing is simple, while the second and fourth are branched. The so-called "true mosquitoes," in the sub-family CULICINAE, are characterized by a long proboscis and scaly wings. They, in turn, are divided roughly into two general groups, the ANOPHELINES (including the genus *Anopheles*) and the CULICINES (almost all the rest of the mosquitoes). Two other groups of delicate, gnat-like mosquitoes resemble the true mosquitoes, but these relatives of the true mosquitoes do not have a long proboscis and can not suck blood, nor do they have scales on the veins of their wings. The larvae, however, are oftentimes difficult for beginners to differentiate. These non-biting mosquitoes are sometimes included in the two sub-families, DIXINAE and CHAOBORINAE and are figured in Plate XV.

RELATION TO MAN: Of all the insects that jeopardize the health of man, mosquitoes rank first. Three genera are of particular medical concern, *Anopheles*, *Aedes*, and *Culex*. Human malaria is transmitted only by mosquitoes of the genus *Anopheles*, and dengue only by the genus *Aedes*. Yellow fever is transmitted from man to man by the common yellow fever mosquito, *Aedes aegypti*. It also occurs as an infection of certain animals of tropical forests, transmitted from animal to animal and incidentally to man, by various species of mosquitoes and, possibly, by other arthropods.

Several genera, including *Culex*, transmit certain species of filaria worms that produce the disease referred to as filariasis. In addition, human encephalitides, caused by various viruses (equine encephalomyelitis, Japanese, St. Louis) are transmitted by mosquitoes. A South American bot fly, *Dermatobia*, often captures and lays its eggs on mosquitoes for transportation to the skin of man or animals, where they hatch and the resulting larvae cause myiasis.

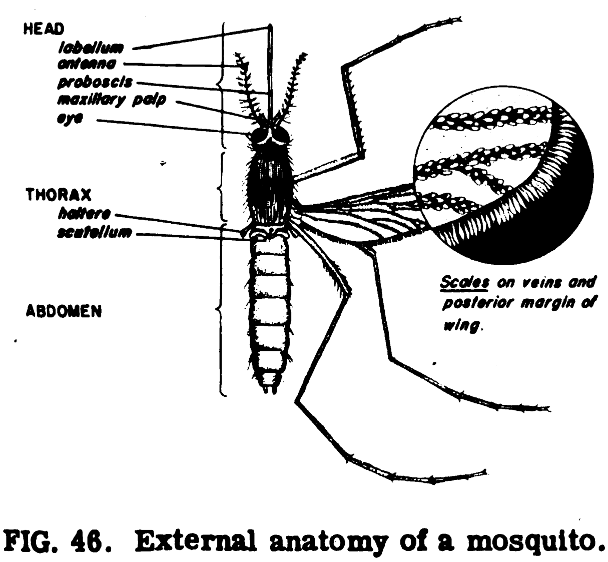


FIG. 46. External anatomy of a mosquito.

EXTERNAL ANATOMY: The adult mosquito possesses one pair of wings and a pair of halteres, characteristics which place it in the order Diptera. Its antennal characters (long and many segmented) assign it to the suborder Nematocera. It falls into the family Culicidae by virtue of its wing venation, the third vein being unbranched between two branched veins, the second and fourth. Finally, the long proboscis and the scales on the veins of the wings place the "true" mosquito in the sub-family Culicinae.

In addition to these characters by which a mosquito is placed in its

assigned order, suborder, family and sub-family, there are several other structures important in generic identification that should be particularly noted: the shape of the <u>scutellum</u>, which is just posterior to the <u>mesonotum</u>; the presence or absence of spotting of the wings due to aggregations of dark and light scales; the length of the <u>maxillary palps</u> in relation to the length of the <u>proboscis</u>; the shape of the tip of the abdomen; and the presence or absence of <u>postspiracular bristles</u> on the side of the thorax just behind the foremost spiracle.

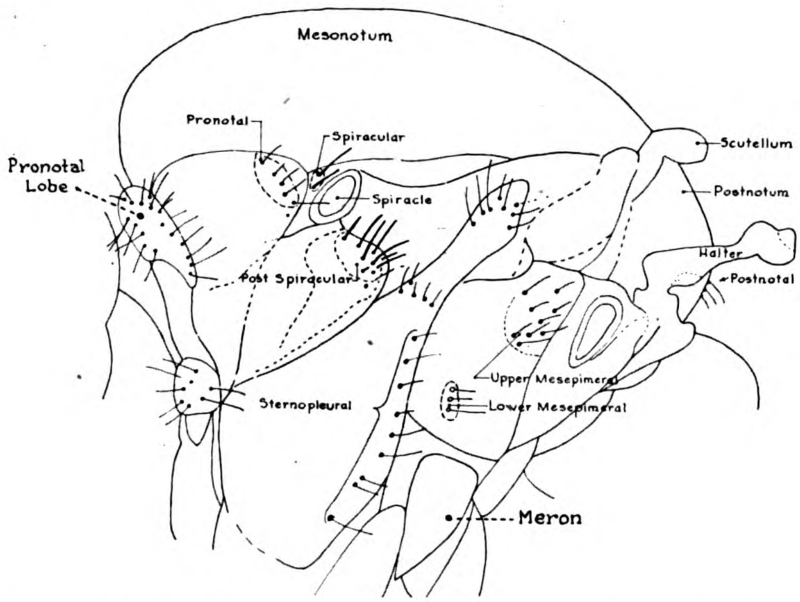


FIG. 47. Side view of mosquito thorax showing location of important diagnostic bristles.

Male mosquitoes may be distinguished readily from females by differences in the antennae. In the male, they are characteristically bushy, whereas in the female they are sparsely haired.

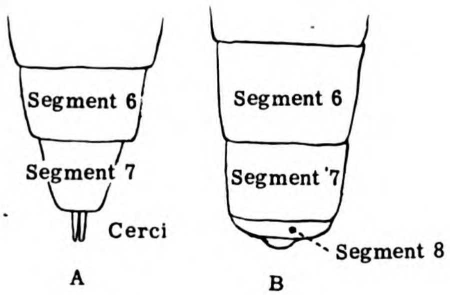


FIG. 48. Characteristic shapes of tip of female abdomen.
A. <u>Aedes</u>. B. <u>Culex</u>.

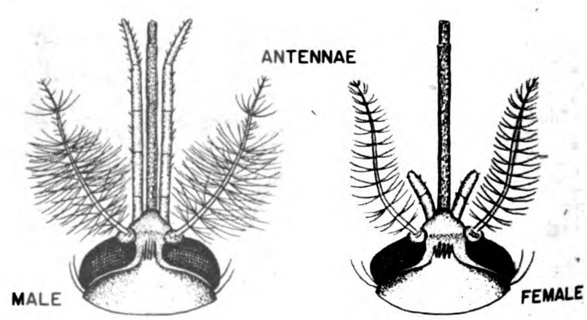


FIG. 49. Sex differentiation of the adult mosquito.

MOUTH PARTS: The elongate gutter-shaped labium encloses the piercing and lacerating stylets of the mouth parts, the entire structure being termed the proboscis. The stylets within are so constructed and arranged as to provide two channels, one for the injection of saliva, the other for sucking up blood.

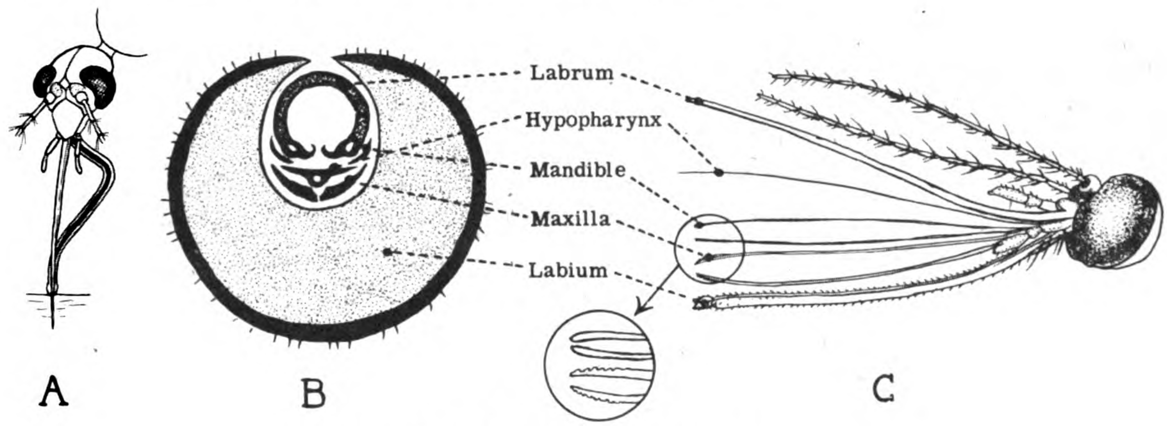


FIG. 50. Mosquito mouth parts.
A. Female mosquito feeding.
B. Cross-section of proboscis.
C. Stylets dissected out of labial gutter.

The labrum is horseshoe-shaped in cross-section with its open side sealed by the close application of the delicate mandibles and hypopharynx. The closed tube thus formed functions as a food canal. The hypopharynx is pierced on its under side for its entire length by the minute salivary duct. Below these tube-forming structures are the principal skin-cutting stylets, the toothed maxillae. When the female mosquito feeds, she works the entire ensemble of stylets into the skin. The lip-like, apical, paired lobes of the labium (labella) continue to grasp the stylets at the skin-surface as they slide in. At the same time, the labial gutter elbows back, leaving the stylets exposed between the head and the labella. Only female mosquitoes feed on blood. In the males, with their mandibles and maxillae very much reduced or lacking, feeding is confined to plant juices or other available sweets.

WINGS AND WING SPOTS: The veins in the wings are characteristically arranged in each group of insects. Thus, in the CULICIDAE the third vein is unbranched and located between two branched veins, the second and fourth. Any mosquito-like insect which does not have this vein-pattern is not a mosquito. In addition, minor variations in the vein-pattern and variations in the grouping, shape, and color of the wing-scales are used in dividing the mosquitoes themselves into groups.

A very few anophelines have unspotted wings; the wings of the great majority, however, show definite dark and light areas which are due to aggregations of dark and light scales. The wing patterns thus produced are characteristic of species and are described in the keys according to the systems illustrated in the two figures below.

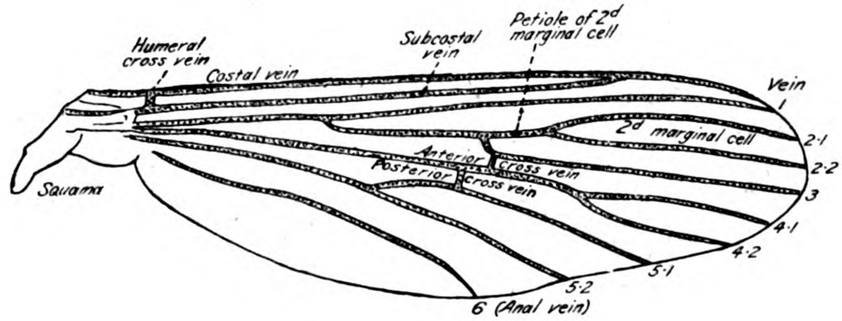


FIG. 51. Denuded wing of mosquito, with veins labeled. The corresponding symbols for the veins in the Comstock-Needham system are: 1, R_1; 2.1 and 2.2, R_2 and R_3; 3, R_{4+5}; 4.1, M_{1+2}; 4.2, M_3; 5.1 and 5.2, Cu_1 and Cu_2; anterior cross vein, r-m; posterior (basal) cross vein, m-cu.

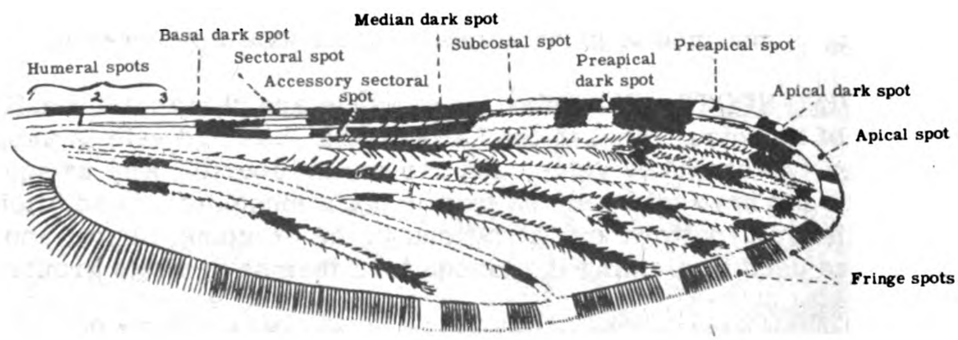


FIG. 52. Anopheline wing with marginal spots designated.

MALE TERMINALIA: The terminal segments of the male abdomen are modified to form organs which function in clasping and impregnating the female. Oftentimes, these terminalia exhibit characteristic structures which are helpful in differentiating species. In order to study these structures satisfactorily, it is necessary to clip off the last few segments of the abdomen, soften and clear them in potassium hydroxide, and mount them on a microscope slide. For details on the preparation of these mounts for study, see page 5, "Mosquito Atlas," Part I, by Ross and Roberts (1943).

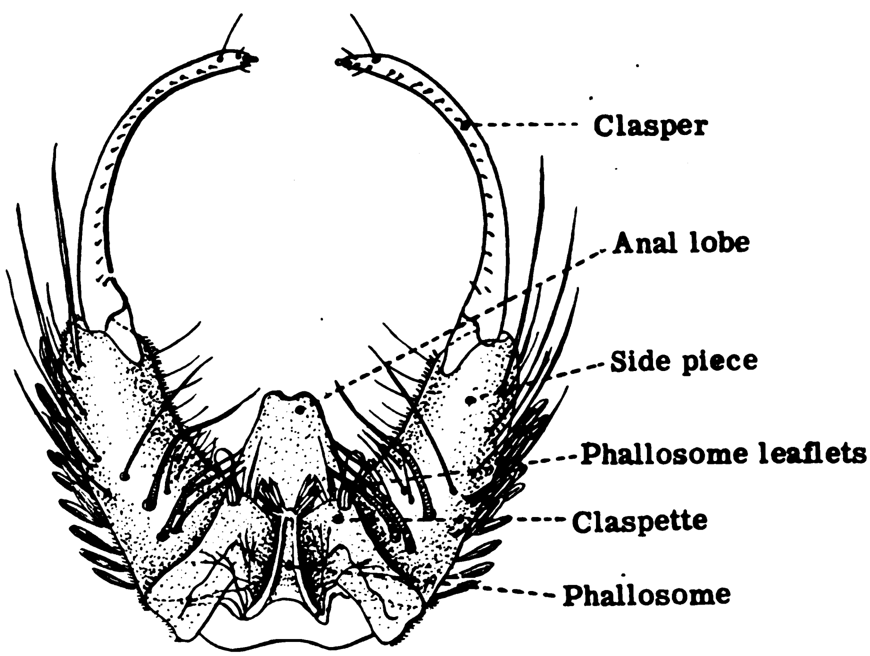


FIG. 53. Male terminalia of an anopheline mosquito.

Among the diagnostic characters of the male genitalia are the elongated, sclerotized phallosome, which is usually surmounted by one or more pairs of small leaflets. The latter frequently vary in number and shape in different species. Below the phallosome, and connecting the bases of the side pieces, is a membrane expanded on each side into a lobe having several spinelike hairs on the posterior margin. The lobes are called the claspettes, and the shape or arrangement of their spines is important in the classification of species. The modified hairs on the side pieces also show differences of subgeneric value.

INTERNAL ANATOMY: The internal organs of a mosquito that are of particular concern in disease transmission are the alimentary canal and its associated salivary glands and malpighian tubules. The malaria plasmodia form their oocysts on the stomach. The mature sporozoites migrate to the salivary glands and thence into the new victim through the saliva. The microfilariae causing filariasis migrate through the wall of the mid-gut into thoracic muscles. Here they change to the "sausage" forms and increase in size, eventually migrating under their own power down through the muscles of the labium and out onto the skin of the victim.

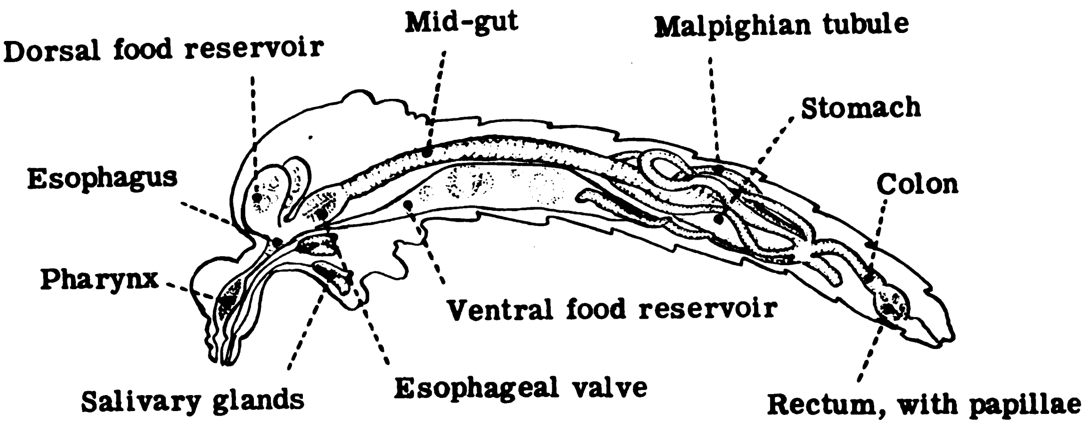


FIG. 54. Alimentary canal of a mosquito.

NOTES

LIFE CYCLE: Egg: The eggs of anopheline mosquitoes are nearly always boat-shaped and provided with "floats." They are laid singly and often arrange themselves in mesh-like geometric patterns as a result of surface tension. Some culicine mosquitoes lay their eggs singly, others stand them on end in rafts which resemble specks of soot floating on the water. Culicine eggs are variously shaped, but have no floats. Mosquito eggs are approximately 1/50 of an inch long.

Larva: When mosquito eggs hatch, tiny larvae, or "wiggle-tails," just visible to the naked eye emerge. As they feed and grow larger, they pass through four instars, shedding their outer skin between each instar. Anopheline larvae are readily recognized in life by the fact that they have no elongate air tube and lie just under the surface film parallel to the water surface. Culicine larvae have a well-developed air tube and hang at an angle from the water surface, touching the surface film only with the tip of the air tube.

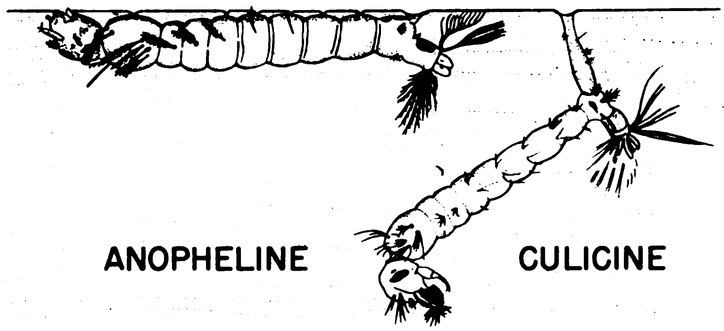


FIG. 55. Positions assumed by larvae of anophelines and culicines at the surface of the water.

Pupa: When its growth is completed, the fourth-instar mosquito larva molts and transforms into a pupa or "tumbler." The pupa moves actively in the water, but does not feed. The enlarged anterior part includes the head and thorax in a single sclerotozed capsule. Two breathing trumpets project from this cephalothorax. The last segment of the abdomen bears a pair of paddles which enable the pupa to "tumble" about.

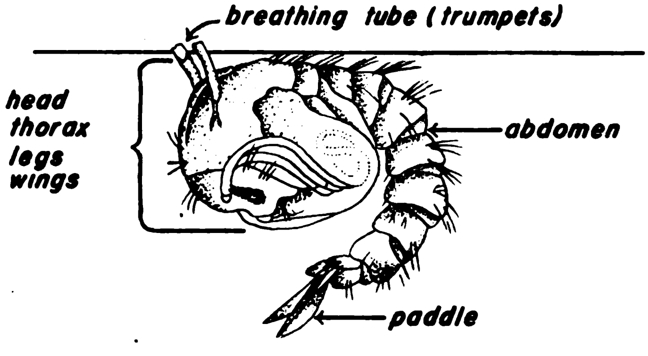


FIG. 56. Pupa of mosquito at surface of water.

Within the pupa, a marked transformation is taking place; new structures are forming which will adapt the insect to terrestrial life. Eventually the adult within emerges through a slit on the back of the thorax, spreads and dries its wings while clinging to the old pupal case on the surface of the water, and flies away.

BIOLOGY: The various species of mosquitoes differ greatly as to rate of development, feeding habits, resting sites of adults, mode of hibernation, choice of breeding grounds, and other characteristics and habits. This "species individuality" has great importance in disease control, since a knowledge of it often enables the entomologist to concentrate control procedures against the particular, important species concerned ("species control"). It also eliminates the necessity for the often far more expensive control measures directed against all kinds of mosquitoes in general.

FEEDING HABITS: Some kinds of mosquitoes do not suck blood; others restrict themselves to non-mammalian blood, attacking birds, reptiles, amphibia, and other hosts. Males do not suck blood, their maxillae and mandibles being so reduced that they are unable to pierce the skin. They supposedly feed on the nectar and juices of plants, as do the females also in some species.

Light, air movement, temperature and humidity, as well as the attractiveness of the host animal and the time since the last feeding influence the biting of mosquitoes.

When a mosquito bites, she first injects a small amount of saliva into her victim. This saliva is generally considered to function as an anticoagulant, but experiments indicate that, with a few species at least, it has no such effect. It is further generally assumed that the irritating effect of mosquito bites is a direct result of the injection of the saliva itself. Careful experiments, again on only a very few species, however, suggest that the irritation (swelling, reddening, and itching) may be due mainly to the regurgitation, into the feeding puncture, of yeasts and enzymes from the alimentary canal of the mosquito.

FLIGHT HABITS: From the standpoint of control, the flight habits of mosquitoes are of much importance. These vary so greatly from species to species and sometimes with locality, that significant generalizations are difficult to make.

The distance that mosquitoes will fly from their breeding places probably varies not only with the species but with the density of adults in the area, the nearness of suitable hosts, and air currents.

HIBERNATION: Some mosquitoes in temperate climates overwinter in the egg stage and hatching begins with the first warm days in spring. In some species the fertilized females hibernate in caves, barns, and similar places. A very few species overwinter as larvae. One of these, Wyeomyia smithi, passes part of its larval stage embedded in ice.

FAMILY CULICIDAE

It is difficult to generalize concerning the seasonal development of mosquitoes in tropical regions. In certain areas, conditions suitable for development are present throughout the year and there is no discontinuity of generations. In other areas, the dry season may be long enough to interrupt the appearance of new generations.

LONGEVITY OF ADULTS: The determination of the length of life of adult mosquitoes under natural conditions is difficult. Obviously, in those species that hibernate as adults, the fecundated females must survive for several months from one breeding season to the next.

Longevity is unquestionably reduced at very high temperatures and very low humidities, conditions which thus have great influence on the transmission of such diseases as malaria. Obviously, if the female mosquitoes cannot live long enough to mature their parasites, they cannot transmit the disease. This condition has actually been shown to prevail in some areas at certain seasons of high temperatures and low humidity.

EGG-LAYING HABITS: The egg-laying habits of mosquitoes vary widely. The factors that influence the female mosquitoes in their selection of sites for egg-laying are not well understood. They may be chemical or physical or both and probably vary greatly from species to species and from area to area.

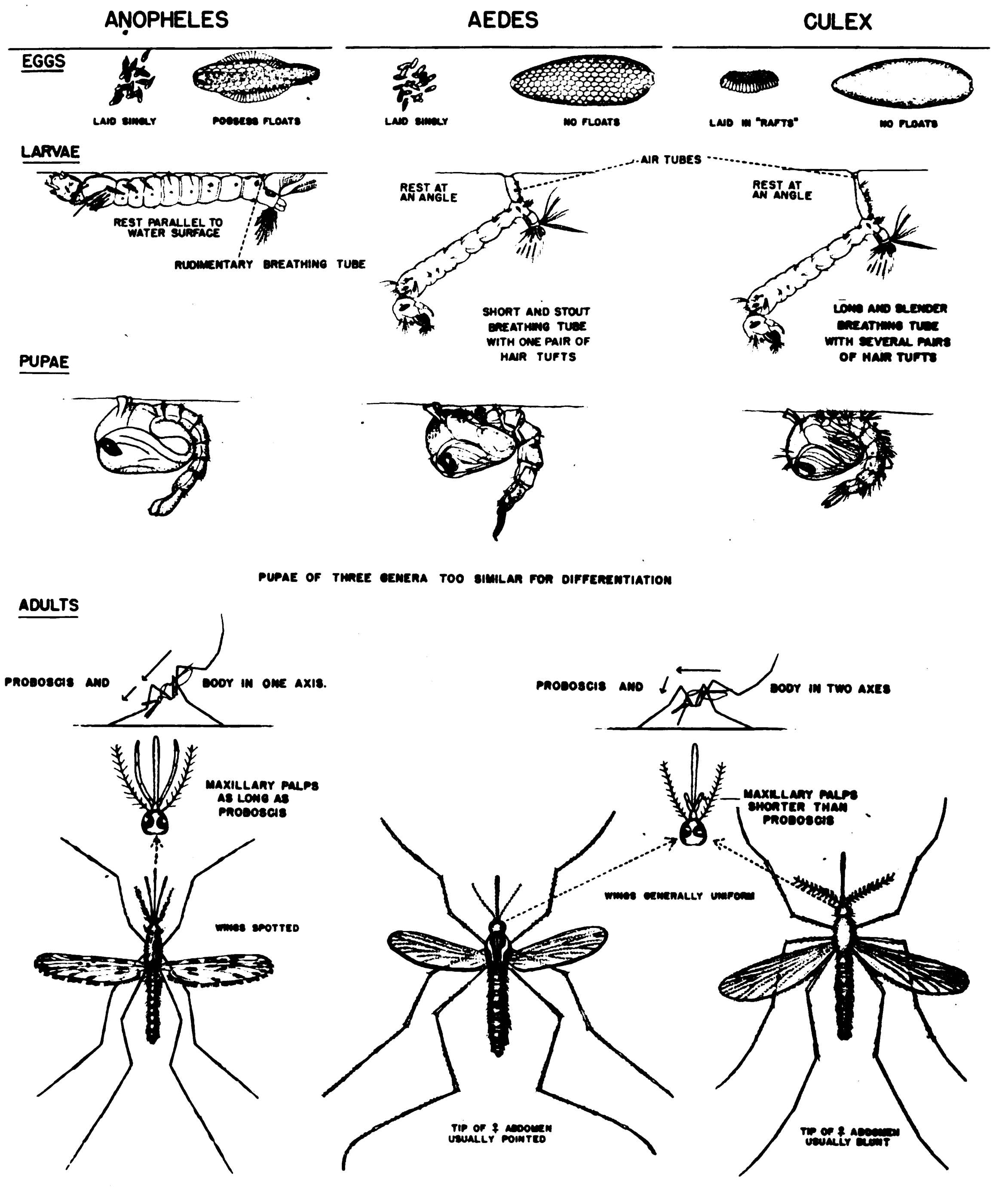
LARVAL HABITS AND HABITATS: All mosquitoes live out their larval lives in water, but the typical breeding places of the different species vary greatly in their characteristics.

It is obvious that control measures must vary greatly, and effective mosquito control in any locality must be based on intimate knowledge of the life habits of the species involved. Control measures for one area may not be effective in another, and adaptations must constantly be made to fit the difference in biology of the species.

In connection with disease control measures, it must be borne in mind that complete elimination of the adults is unnecessary, for below a certain minimum density, mosquito-borne diseases will disappear of their own accord. This minimum number of mosquitoes necessary to perpetuate disease depends upon many factors, and no formula is available from which this number can be readily determined. However, since even very careful field control measures rarely result in complete elimination of mosquitoes, it is still important to strive for as complete elimination as possible and to use every means available to attain this end.

PLATE XVI

PRINCIPAL CHARACTERS FOR IDENTIFYING THE THREE GENERA OF MEDICAL IMPORTANCE



FAMILY CULICIDAE

Key To The Three Genera Of Mosquitoes Of Greatest Medical Importance

EGGS:

1. Eggs laid singly. 2

   Eggs laid in groups called "rafts"; individual eggs without floats. . . . . Culex

2. Eggs with floats. . . . . Anopheles

   Eggs without floats. . . . . Aedes

LARVAE:

1. Larvae rest parallel to surface of water; breathing tube rudimentary; a series of palmate or float hairs on the abdomen. Anopheles

   Larvae rest at an angle to the surface of water; well developed breathing tube; without palmate or float hairs on the abdomen. . . . 2

2. With a single tuft of hairs beyond each row of pecten teeth on breathing tube. . . . . Aedes

   With more than one hair tuft beyond each row of tecten teeth on breathing tube. . . . . Culex

ADULTS:

1. Scutellum evenly rounded; wings usually spotted; maxillary palps of female as long or nearly as long as proboscis; resting position with proboscis and body in one axis. . . . . Anopheles

   Scutellum trilobed; wings not spotted; maxillary palps of female much shorter than proboscis; resting position with proboscis and body in two axes. 2

2. Postspiracular bristles present; tip of abdomen of female usually pointed; cerci protruding; thorax often with silver or white markings. . . . . Aedes

   Postspiracular bristles absent; tip of abdomen of female usually blunt; cerci retracted; thorax usually dull-colored. . . . . Culex

FAMILY CULICIDAE

GENUS CULEX

GENERAL CHARACTERISTICS: Members of the genus Culex, of which there are about 300 species, are among the commonest mosquitoes. Their scutellum is tri-lobed; the abdomen is blunt and completely clothed with scales; and postspiracular bristles are absent. The mesonotum is usually not conspicuously ornamented with white. The larvae have a somewhat elongated air tube with well-developed pecten and usually several hair tufts beyond the pecten. The adults lay their eggs in rafts, usually with a hundred or more eggs in each raft, in various kinds of artificial containers, or in ground pools, either in the open or in deep woodlands. In temperate regions, they usually overwinter as adults in caves, barns, and similar places.

Culex quinquefasciatus (= fatigans): This is a common house mosquito and an important pest in the warm temperate, tropical, and subtropical regions of the world. The proboscis and tarsi are without light-colored bands, the mesonotum is uniformly brown, and the abdominal segments have dorsal basal transverse bands. The air tube of the larva bears four hair tufts, all on the ventral side. It is $3\frac{1}{2}$ times as long as its greatest diameter, the tube being widest at about 1/3 the distance from the base.

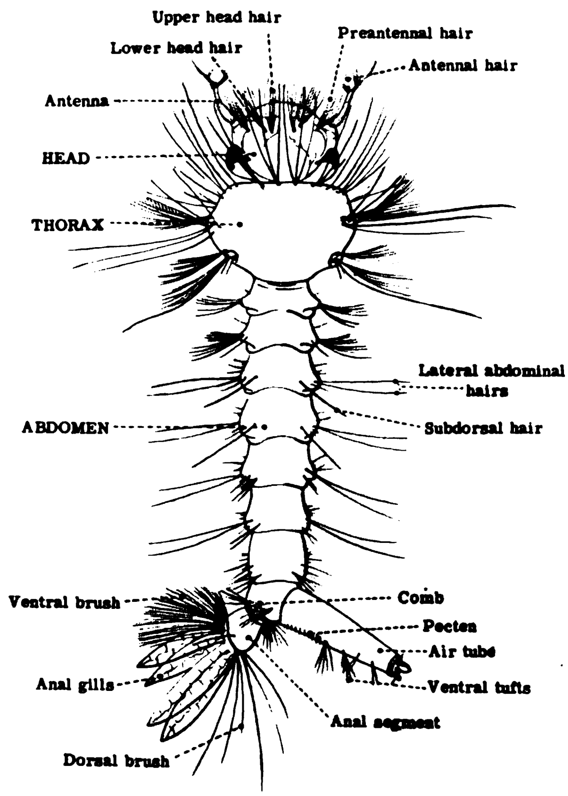


FIG. 57. Larva of Culex quinquefasciatus

GENUS *CULEX*

RELATION TO MAN: *Culex quinquefasciatus* is one of the important vectors of filariasis caused by *Wuchereria bancrofti*.

LIFE CYCLE AND HABITS: The larvae of this species are found most commonly near human dwellings in artificial containers, such as water barrels and in small ground pools, especially in polluted water. They complete their development in about a week or ten days. The adults are night-feeders and take the blood of man readily.

CONTROL: The control of *Culex quinquefasciatus* consists in the removal or overturning of all water-holding containers and the drainage or filling of all pools near human habitations. Where these procedures are not feasible, kerosene or fuel oil should be sprayed on the water surfaces. In special cases where this might be objectionable because of the taste or odor imparted to the water--as in water-barrels or cisterns--these containers should be screened or surface-feeding fish introduced into them. A light, volatile oil, such as non-leaded gasoline or odorless kerosene may also be used in such situations.

NOTES

FAMILY CULICIDAE

GENUS *AEDES*

GENERAL CHARACTERISTICS: The genus *Aedes* includes some 500 different species and is the largest single genus of mosquitoes. Aedines can be distinguished from most other common mosquitoes by the tapered end of the abdomen and the projecting cerci; by the presence of postspiracular bristles and the absence of spiracular bristles. The eggs of most *Aedes* are not laid on or in water, but on the ground along dry margins or at the bottoms of dried-out pools, ponds, marshes, swamps, etc., or above the water level on the edges of containers. Here they remain unhatched until submerged by water. In some of the northern species, the eggs will not hatch the same season even if submerged; thus, these species usually emerge in one great brood the following spring. Other species breed continuously throughout the year. The larvae have a short stout breathing tube with a single pair of hair tufts beyond the pecten.

While many *Aedes* are important pest species, only a few are of primary concern in disease transmission. These important disease vectors all belong to the subgenus *Stegomyia* and are highly ornamented forms with conspicuous silver or white markings on the thorax, abdomen, and legs.

RELATION TO MAN: Three species of *Aedes* (*Stegomyia*) are particularly well-known because of their ability to transmit important tropical diseases. *Aedes aegypti*, a highly domestic species, is the important cosmopolitan vector of urban yellow fever and of dengue. *Aedes albopictus* is an oriental species proven to transmit dengue in the Philippines and elsewhere in the oriental region. *Aedes scutellaris* is typically Australian in distribution, and its several varieties are distributed throughout the South Pacific Islands. *Aedes scutellaris pseudoscutellaris* is the principal vector of non-periodic filariasis in the Samoan-Fijian area. In addition to *aegypti* and *albopictus*, *scutellaris* and its varieties are probably important dengue vectors wherever they occur in numbers. Several other species of *Aedes*, as well as *Culex*, are involved as vectors of human encephalitis.

LIFE CYCLE AND HABITS: While most *Aedes* species breed in temporary rain pools, floodwaters, and tidal marshes, those species which are of greatest medical importance are totally different in their choice of breeding sites. These larvae, while originally occurring in tree-holes or other natural cavities, have in many cases largely transferred to artificial containers of various types in the vicinity of man's habitations. This is especially true of *Aedes aegypti*, and to a lesser extent of the other species. They are not found in naturally occurring ground pools, an important consideration in their control.

The black, oval eggs are laid on the sides of water containers, usually just above the water line. These containers may dry out completely, and the eggs may remain dormant for weeks or even months. When the containers are refilled or their water levels raised, the eggs are flooded and hatch almost immediately.

The larva develops in six to eight days under favorable conditions and changes

into the pupa, from which the adult emerges two days later. Thus, the total life cycle may be completed in nine to twelve days.

The adults are avid biters, feeding throughout the day, especially in the early morning and in the late afternoon, and are usually very common about buildings and other shelters. They do not fly more than a few hundred yards; hence, when they become troublesome, the breeding source can usually be found nearby. This is in strong contrast to other *Aedes* species, especially the salt marsh forms which may migrate twenty to forty miles from their breeding grounds.

CONTROL: Control of these mosquitoes is best accomplished by elimination of their breeding places. Since they are often highly domestic, it is important to make weekly inspections of a station or camp area and to eliminate as far as possible all temporary water containers. Tin cans, bottles, jars, pails, old tires, sagging eave troughs, rain barrels, fire buckets, cisterns, watering troughs, etc., are common breeding places. Under military conditions, many other peculiar sites may be utilized, such as the tops of 50-gallon drums, bomb crates, sections of prefabricated buildings, crated machinery, etc., including almost any situation where a small pocket of water may be held for ten days or more. In the tropics, coconut shells and halved cacao pods may also contain these larvae, so that some plantations have hordes of pests as well as potential disease vectors wherever these halved shells are left in the groves. Although *Aedes aegypti* is not commonly found in treeholes, *A. scutellaris* and *A. albopictus* may be found in these locations as well as in the above named breeding places. Where these treeholes cannot be drained, they may be filled with earth or sand, or oiled at intervals.

Wherever these artificial containers cannot be eliminated, they should be carefully screened or covered to exclude mosquitoes, or carefully emptied once every week to destroy any larvae present. Such water collections can be oiled or treated with borax to prevent breeding. A handful of borax in a rain-barrel is sufficient, and the water can still be used for washing dishes or clothing. In open wells, water barrels or cisterns, a light volatile oil such as non-leaded gasoline or kerosene can be used. This will kill the larvae quickly and will soon evaporate, leaving the water suitable for drinking and washing purposes.

Camp inspections are extremely important in control of these species of *Aedes*. Since the eggs often remain dormant and hatch as soon as containers are filled with water, it is possible that a whole generation of *Aedes* may emerge and the container again become dry within an eight to ten day period. Inspection for breeding places should then include a search for all potential breeding places as well as for the larvae themselves. Thus, frequent and thorough inspection by men experienced in this type of control work is an essential part of any dengue or yellow fever control campaign. It cannot be emphasized too strongly that this program is totally different from malaria control. The *Aedes* involved here must be controlled by treatment or elimination of artificial water containers, while the *Anopheles* are controlled in naturally occurring ground waters.

GENUS *AEDES*

The three important species of *Aedes* can be separated by the thoracic markings of the adult, but larval distinctions are not so apparent. The lyre-shaped silvery markings on the mesonotum of *A. aegypti* are distinctive of that cosmopolitan species. In both *A. albopictus* and *A. scutellaris*, including its varieties, a median silver stripe is found on the mesonotum but the pleural markings differ. In *A. albopictus*, the silver scales on the side of the thorax are arranged in spots, while in *A. scutellaris* these are arranged in three lines.

The larvae of all three species are very similar, those of *Aedes aegypti* differing from the other two in the conspicuous thorn-like processes at the base of the lateral thoracic hair tufts and in the conspicuous secondary spines on the comb scales. These characters are not present in *A. albopictus* and *A. scutellaris*; hence their separation is difficult on other than geographic grounds or the rearing of adults.

GEOGRAPHICAL DISTRIBUTION OF MEDICALLY IMPORTANT *AEDES*

Aedes aegypti (yellow fever and dengue)	World wide in tropical and subtropical climates.
Aedes albopictus (dengue)	Oriental region; also in Celebes, Dutch East Indies, Northern Australia, New Guinea, Hawaiian Islands (introduced).
Aedes scutellaris and varieties	Australian region:
A. scutellaris scutellaris (dengue?)	Solomon Islands, New Guinea, Dutch East Indies.
A. scutellaris hebrideus (dengue)	New Hebrides, New Guinea
A. scutellaris pseudoscutellaris (Bancroft's filariasis) (dengue)	New Hebrides, Samoa, Fiji, Ellice Islands, Marquesas Islands, Society Islands.
A. scutellaris tongae (dengue?)	Friendly Islands, Sikiana (Solomon Group)
A. scutellaris andrewsi (dengue?)	Christmas Island (south of Java)
A. scutellaris horrescens (dengue?)	Fiji

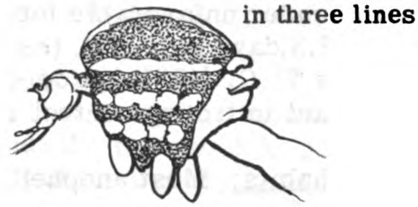
PLATE XVII

DIAGNOSTIC CHARACTERS FOR DISTINGUISHING MEDICALLY IMPORTANT AEDES

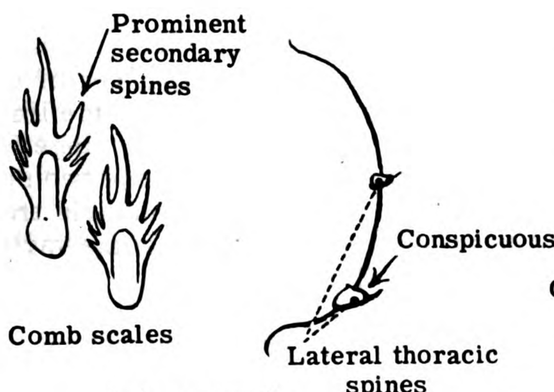
Aedes aegypti

Aedes albopictus
and Aedes scutellaris

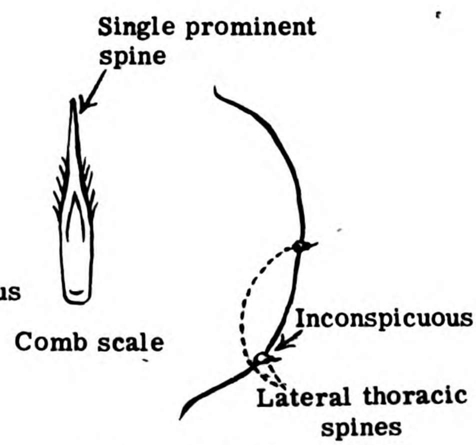
Aedes albopictus



Aedes scutellaris



Aedes aegypti



Aedes scutellaris
and Aedes albopictus

FAMILY CULICIDAE

GENUS *ANOPHELES*

GENERAL CHARACTERISTICS: Members of the genus *Anopheles* are characterized by their spotted wings; evenly rounded, crescent-shaped scutellum; the long palpi in the female; the absence of scales on the first abdominal tergite; and by their peculiar habit of "standing on their heads" when resting on a surface. The larvae have no breathing tube and lie close under the surface of the water, suspended from the surface film by special palmate hairs on the dorsal surface of the abdomen. They feed primarily on floating material. The eggs are laid singly and bear so-called "floats."

RELATION TO MAN: From the standpoint of human disease, the anophelines are the most important mosquitoes, largely because they are the exclusive vectors of human malaria, the most important single infectious disease of man. In some parts of the world (India, Africa, Melanesia) they are also important transmitters of filariasis.

LIFE CYCLE AND HABITS: Rate of development: Most anopheline species require approximately eight to fourteen days for their development from egg to adult under optimum conditions of temperature, food, etc. A longer time is required at low temperatures and under unfavorable food conditions. Thus *Anopheles quadrimaculatus* requires only 7.3 days at 31° C. (88°F.), while at 12°C. (54°F.) it requires 65.5 days, and below 7° C. (45°F.) it does not develop at all. Rate of larval development is very important in timing control measures.

Feeding habits: Most anophelines readily attack man, but some of them unquestionably prefer other mammalian blood and are thus at least partially zoophilic. With these forms, there is considerable evidence that the presence of the larger domesticated animals near human abodes may reduce their attacks on man.

Anophelines feed characteristically at dusk or at night, although many species will feed on cloudy, humid days or in heavy shade; and occasionally, rare individuals will bite even in bright sunshine.

Flight habits: *Anopheles quadrimaculatus*, the principal vector of malaria in the Southeastern United States, and *A. punctulatus moluccensis*, the important vector in the South Pacific Island, evidently have an "effective" flight range for malaria transmission of one mile or less. Thus, if the breeding of these two species within one mile of any particular, inhabited place is prevented, no malaria transmission will occur in that place. In North Africa, on the other hand, some varieties of *A. maculipennis* are thought to have an effective flight range of several miles. Certainly, no "magic mile" should be relied upon blindly, but rather the flight range of each species in each region in which the control is being done should be investigated in the literature and verified by observation or experiment as the control work progresses.

Hibernation: In temperate regions, members of the genus *Anopheles* usually

overwinter as adults in cellars, caves, treeholes, and barns. Anophelines overwintering in warm stables and homes may play an important though circumscribed role in the transmission of malaria.

Longevity of adults: Preliminary observations on caged individuals of *Anopheles punctulatus moluccensis* would place the length of life of females at about 35 days (temperature and humidity unstated); of males, at about two weeks. Other species have been estimated to live from 30 days to three months in nature, and anophelines have been kept alive in the laboratory for as long as eight months.

Larval habits and habitats: Larvae of the genus *Anopheles* are found in a great variety of breeding areas. The pools covered with "green scum," which the unsophisticated point out with a shudder as "dreadful malaria holes," are known now not to be the only source of anopheline breeding. A study of the anopheline fauna of the whole world reveals that some species of *Anopheles* will breed in almost any conceivable water-collection. Some species have a wide range of habitats, while others are very restricted in their breeding.

The great majority of anopheline species probably prefer the comparatively pure, standing, fresh water of pools, ponds, marshes, and swamps, but there are many exceptions to this rule. Some few species,like *Anopheles subpictus* in the Netherlands Indies, are said to prefer polluted water; *A. maculatus* in the Orient breeds in swift-flowing streams; *A. barberi* and *A. bellator* breed only in water-holding plants, or in the water held in rot-holes in trees; and the oriental *A. asiaticus* breeds in cut bamboo stalks. On the other hand, the larvae of *A. punctulatus moluccensis* in the South Pacific have been found in almost every type of fresh and brackish water inhabited by mosquitoes. Its breeding places range from margins of large lakes to hoofprints and tins cans; from swift streams through all gradations to stagnant swamps; from densely turbid water to crystal-clear springs; from relatively cool water to hot springs; from pools and streams with dense vegetation to puddles with no apparent plant growth; from open, sunlit areas to shaded pools and even wells.

Precipitation and seasonal cycle: The effect of precipitation on anopheline breeding is most evident in regions where rainfall is largely limited to certain seasons of the year and where the important anopheline is a rain-pool breeder. The rains result in a great increase in the number and size of surface pools which persist for some time after the period of maximum rainfall. Usually then, a maximum production of pool breeders occurs just after the peak of the rainy season. This is well illustrated by the seasonal incidence of *Anopheles punctulatus moluccensis* in the South and Southwest Pacific.

In areas where breeding of the local vector is more limited to streams, the largest numbers are usually produced during the dry season when the rains and heavy flushing floods subside and a more stable stream flow is established.

Anopheles punctulatus moluccensis, breeding in both pools and streams, is

commonly encountered along stream margins during the dry season, but in the rainy season, the larvae are flushed from their protected breeding places by frequent heavy floods. Thus this species is abundant in pools during the rainy season, but is not found in those streams subject to frequent floods until the dry season.

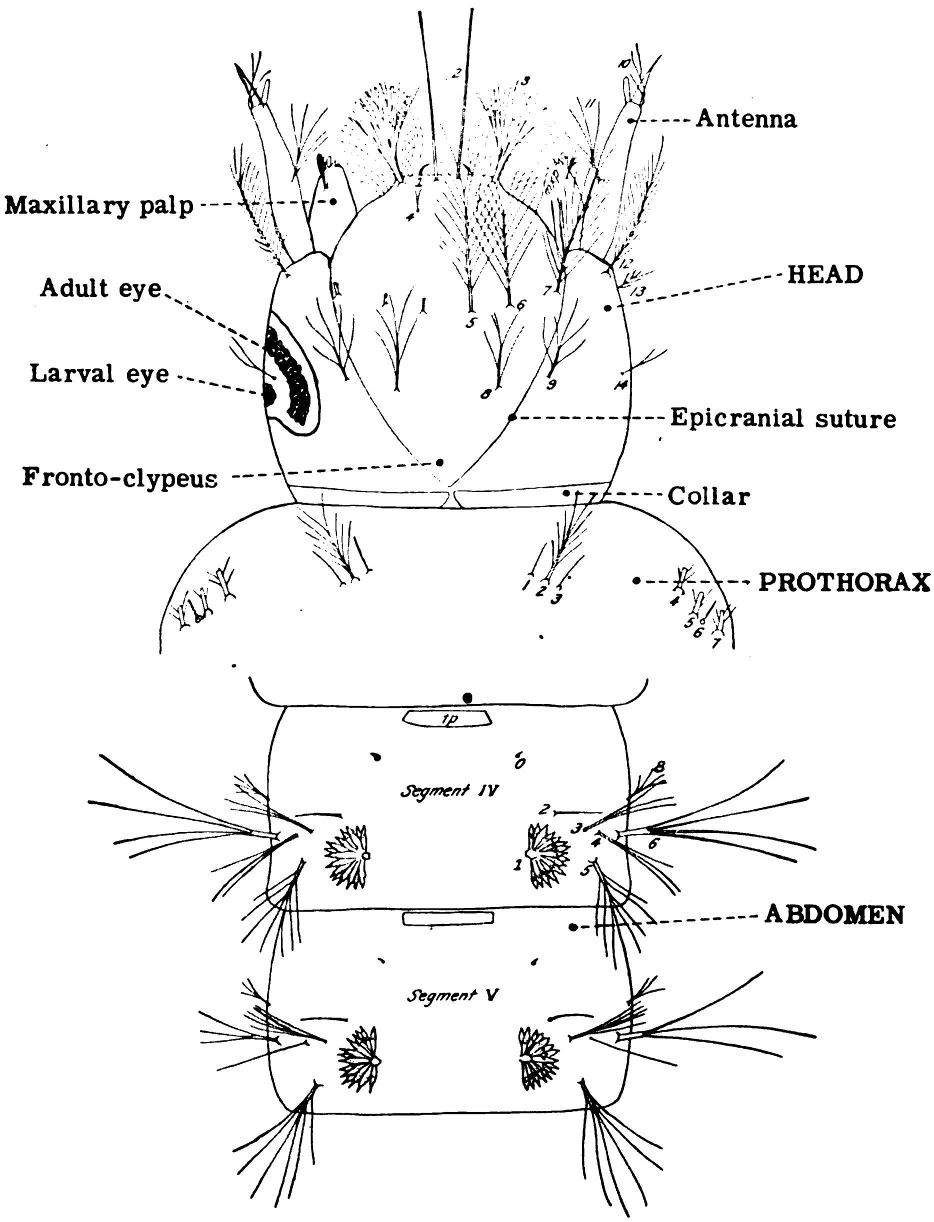
When periods of maximum precipitation and temperatures coincide, temporary water accumulations will probably be the important anopheline production areas. Where dry summers are the rule, the breeding will be restricted to permanent water.

IDENTIFICATION OF ANOPHLINES: For keys to species of Anopheles consult "Keys to the Anopheline Mosquitoes of the World," by Russell, Rozeboom, and Stone (1943); "The Mosquito Atlas," Parts I and II, Ross and Roberts (1943); and "The Anopheline Mosquitoes of the Northern Half of the Western Hemisphere and of the Philippine Islands," by Simmons and Aitken (1942), Army Medical Bulletin No. 59. A discussion of Dutch East Indies anophelines is included in "Epidemiology of Diseases of Military Importance in the Netherlands East Indies," by Farner (1943). Exceptional care must be taken in the identification of species in the southwest Pacific area because of the large number of closely related species involved and the confusion of scientific names in the older literature. There is also the possibility of undescribed species being found in those less well-known areas where extensive malaria control activities are now being practiced. Whenever there is any question as to the exact identity of species involved, such material may be sent to the Medical Officer in Command, Naval Medical School, National Naval Medical Center, Bethesda, Maryland, for examination. Instructions for collecting, preparing and shipping such material are given in the discussion of Entomological Techniques, Section IV.

NOTES

PLATE XVIII

ANOPHELINE LARVAL CHARACTERS



HEAD

Clypeal hairs
1. preclypeal
2. inner clypeal
3. outer clypeal
4. postclypeal

Frontal hairs
5. inner frontal
6. mid-frontal
7. outer frontal

Sutural hairs
8. inner sutural
9. outer sutural

Antennal hairs
10. terminal antennal
11. antennal
12. basal antennal
13. sub-basal antennal

Orbital hairs
14. orbital

PROTHORAX

Submedian hairs
1. inner submedian
2. middle submedian
3. outer submedian

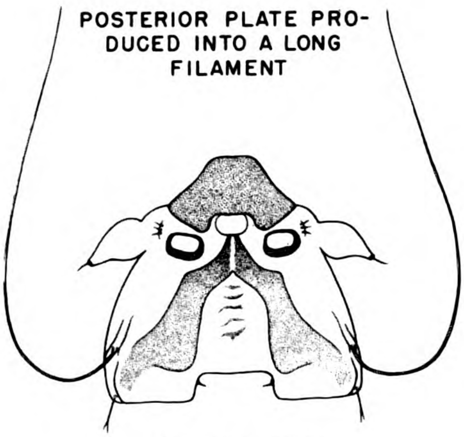
Lateral hairs
4-7. lateral

ABDOMEN

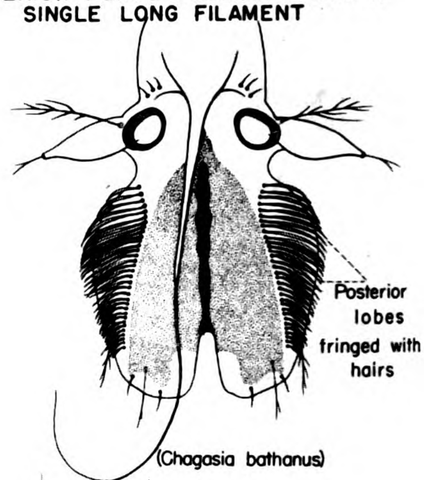
Abdominal hairs
0. anterior submedian
1. palmate
2. antepalmate
3-5. sublateral
6-8. lateral

PLATE XIX

ADDITIONAL CHARACTERS OF ANOPHELINE LARVAE

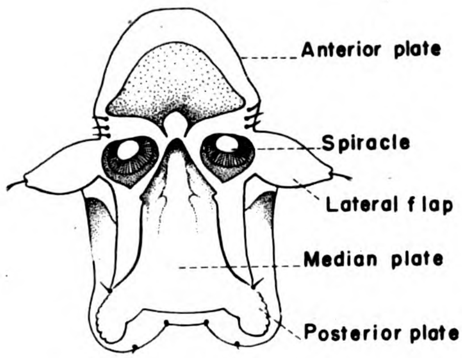


(Anopheles darlingi)



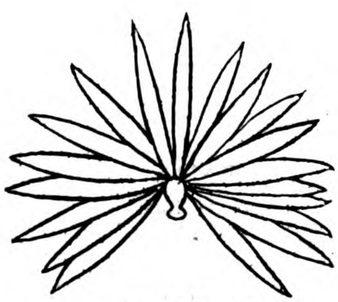
(Chagasia bathanus)

COMB OR PECTEN TEETH
(Sub equal)

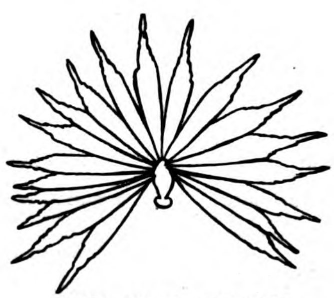


RESPIRATORY APPARATUS

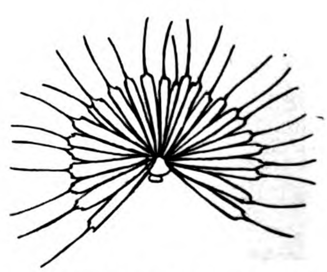
COMB OR PECTEN TEETH
(Long & short)



LANCEOLATE



SERRATE - TIPPED

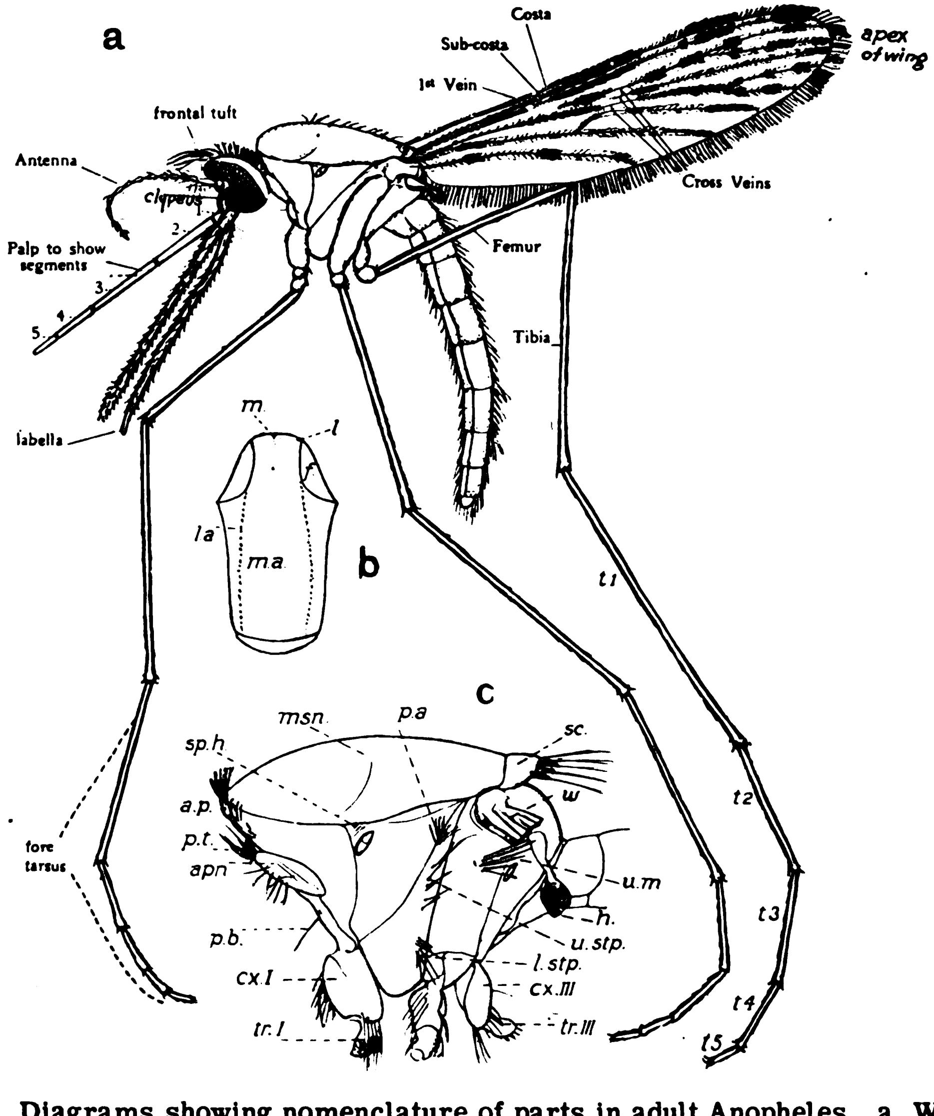


FILAMENTOUS-TIPPED

PALMATE HAIRS

PLATE XX

ADULT ANOPHELINE CHARACTERS.



Diagrams showing nomenclature of parts in adult Anopheles. a. Whole insect (female) in side view, showing main parts of body. b. Upper surface (dorsum) of thorax. m.a., median area; l.a., lateral area; f., fossa; m., median and l., lateral positions on anterior promontory where scales are commonly attached. c. Side of thorax, showing areas, bristles, etc. a.p., anterior promontory; apn., anterior pronotal lobe; cx. I, front coxa; cx. III, hind coxa; h., haltere; l.stp., lower sternopleural or mesepisternal bristles; p.a., prealar tuft of bristles; p.b., propleural bristle; p.t., pronotal scale tuft; sp.h., spiracular hairs or bristles; tr. I, front trochanter; tr. III, hind trochanter; u.stp., upper sternopleural or mesepisternal bristles; u.m., upper mesepimeral bristles; w., base of wing.

CONTROL OF MALARIA VECTORS

THE MORE COMMON OR MORE GENERALLY TYPICAL BREEDING PLACES OF THE MOST IMPORTANT SPECIES OF ANOPHELES MOSQUITOES TRANSMITTING MALARIA IN VARIOUS REGIONS AND THE PRINCIPAL CONTROL METHODS WHICH MAY BE EMPLOYED

REGION	*Brackish water swamps, pools and marshes, usually open to sunlight*	*Fresh water swamps, usually open to sunlight*	*Fresh water swamps, pools, shaded. Water under jungle or swamp vegetation*	*Large rivers, fast or slow, grassy edges (stream bed pools)*	*Small streams, ditches, seepages, moderate current, grassy sides, clear water*	*Hill streams, free from grass, very slow current, clear water*	*Hill streams, free from grass, rapid current, clear water*	*Irrigation channels, with bays or pockets, grassy sides, average current*	*Shallow seepage, clear water, from irrigation or streams*	*Reservoirs, impounded water, ponds, bayous, lakes*	*Rain water pools, especially if containing algae. Rock pools*	*Springs, small pools, hoof-prints*	*Rice fields*	*Open wells*	*Tanks in open air, or dark wells in houses*	*Artificial containers, cans, coconut shells, gourds, boats, etc.*
South Pacific Islands	A. punctulatus moluccensis	A. punctulatus moluccensis A. p. punctulatus	A. punctulatus moluccensis A. p. punctulatus	A. punctulatus moluccensis	A. punctulatus moluccensis	A. punctulatus moluccensis		A. punctulatus moluccensis	A. punctulatus moluccensis	A. punctulatus moluccensis	A. punctulatus moluccensis	A. punctulatus moluccensis A. p. punctulatus		A. punctulatus moluccensis		A. punctulatus moluccensis
Netherlands Indies	A. sundaicus A. subpictus		A. umbrosus (also in brackish water)		A. maculatus (in sunlight) A. barbirostris	A. minimus flavirostris A. maculatus (in sunlight)	A. maculatus (in sunlight) A. kochi	A. aconitus		A. kochi	A. subpictus (usually polluted)	A. leucosphyrus	A. aconitus A. hyrcanus sinensis			
Philippine Islands					A. minimus flavirostris A. maculatus	A. minimus flavirostris	A. minimus flavirostris							A. minimus flavirostris		
Malaya	A. sundaicus		A. umbrosus		A. maculatus(?) A. barbirostris	A. maculatus	A. maculatus	A. aconitus		A. philippinensis			A. annularis (fuliginosus)	A. umbrosus		
Burma	A. sundaicus				A. minimus A. maculatus	A. maculatus	A. maculatus	A. minimus		A. philippinensis			A. minimus A. philippinensis			
India	A. sundaicus	A. annularis		A. superpictus A. jeyporensis	A. minimus A. fluviatilis	A. superpictus (Baluchistan)		A. culicifacies A. minimus		A. philippinensis (in open ponds)	A. culicifacies A. stephensi A. minimus varuna		A. culicifacies A. annularis	A. stephensi A. culicifacies A. minimus varuna	A. stephensi	A. stephensi
Ceylon				A. culicifacies (in sand pools)	A. minimus A. fluviatilis								A. minimus	A. culicifacies A. minimus varuna	A. stephensi	
Thailand, Indo-China		A. tesselatus		A. culicifacies A. jeyporensis	A. minimus A. culicifacies A. maculatus A. barbirostris	A. minimus A. maculatus	A. maculatus	A. culicifacies		A. minimus (?)			A. minimus A. culicifacies A. hyrcanus sinensis	A. culicifacies		
China		A. tesselatus		A. jeyporensis	A. minimus A. maculatus	A. minimus A. maculatus A. pattoni	A. maculatus	A. minimus A. hyrcanus sinensis			A. subpictus		A. hyrcanus sinensis A. minimus A. pattoni			
Near East	A. sacharovi (elutus)			A. culicifacies A. superpictus	A. culicifacies A. superpictus						A. gambiae A. superpictus	A. sergenti			A. stephensi A. claviger	A. stephensi
North Africa	A. maculipennis labranchiae	A. algeriensis A. pharoensis		A. superpictus	A. superpictus			A. multicolor				A. sergenti	A. maculipennis labranchiae			
Central and South Africa		A. funestus A. pharoensis		A. funestus A. nili A. hargreavsi	A. gambiae A. funestus				A. gambiae A. funestus		A. gambiae A. moucheti	A. gambiae A. funestus		A. gambiae		A. funestus A. gambiae
Italy, Balkans, Spain	A. maculipennis labranchiae (also var. atroparvus in Spain and Portugal) A. sacharovi (elutus)			A. superpictus	A. sacharovi (elutus) A. superpictus	A. superpictus						A. sacharovi (elutus)	A. maculipennis labranchiae			
Russia, Eastern Europe	A. sacharovi (elutus)	A. maculipennis messeae A. m. maculipennis		A. superpictus	A. sacharovi (elutus) A. superpictus	A. superpictus			A. maculipennis maculipennis			A. sacharovi (elutus) A. m. maculipennis				
South America		A. albitarsis A. albimanus		A. pseudopunctipennis (pools, algae) A. darlingi	A. argyritarsis					A. albitarsis	A. darlingi and A. bellator (also in bromelaids)	A. tarsimaculatus				
Central America West Indies	A. tarsimaculatus	A. albimanus	A. punctimacula	A. pseudopunctipennis (pools, algae)							A. albimanus	A. tarsimaculatus				
Southern North America		A. quadrimaculatus		A. quadrimaculatus	A. quadrimaculatus			A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus	A. quadrimaculatus			
Western North America					A. punctipennis				A. maculipennis freeborni			A. maculipennis freeborni				
EFFECTIVE MOSQUITO CONTROL MEASURES WHICH ARE APPLICABLE TO THESE TYPE BREEDING PLACES																
Until adequate mosquito control is established, especially in tropical areas, fairly good malaria control may be obtained by hand-catching or spray killing adult Anopheles in quarters or tents, night and morning.	Open marsh ditching. Dykes, tide gates and ditches. Filling (hydraulic and natural). Increase salt content of water by flooding with sea water. Decrease salt content of water by flooding with fresh water. Oiling. Paris green.	Drainage. Natural and artificial fill. Enclosure by dykes, with flooding plus larvicidal fish. Pollution with decaying vegetation. Oiling. Paris green. Pyrethrum larvicides. Shading.	Drainage. Natural and artificial fill. Clearing to let in sunlight. Pollution with decaying vegetation. Oiling. Paris green. Pyrethrum larvicide.	Channelising of river stream. Controlled silting of stream bed sides. Clear away or poison grass. Oiling. Paris green. Pyrethrum larvicide.	Subsoil drainage. Open drainage with dense shade. Flushing. Oiling. Larvicidal fish. Paris green.	In Malaya, dense shade, flushing, oiling, subsoil drainage. Elsewhere flushing, channelising of stream bed. Oiling. Paris green.	Flushing. Continuous drip oiling. (Dense shade against A. maculatus)	Intermittent irrigation. Reshape canal banks. Clear vegetation away. Larvicidal fish. Oiling.	Restriction of excessive use of irrigation water. Canal and ditch lining to reduce seepage. Larvicidal fish. Vertical drainage. Pump out low areas and return water to irrigation canals. Oiling. Paris green. Pyrethrum larvicide.	Clear reservoir bottoms of all vegetation before filling. Fluctuating water levels. Larvicidal fish. Clear vegetation from banks. Oiling. Paris green.	Drainage. Filling. Oiling. Paris green. Pyrethrum larvicide.	Subsoil drainage. Drainage. Oiling. Paris green. Pyrethrum spray on springs used for drinking water.	Intermittent drying. Carefully level paddies before planting. Keep banks clear of vegetation. Muddying water. Larvicidal fish. Pyrethrum larvicide. Oiled sawdust.	Fill in, if not in use. Cover with mosquito-proof cover. Larvicidal fish? Pyrethrum spray. Oiling with a light oil such as kerosene.	Mosquito-proof covers or screens. Frequent change of water with surface disturbance. Larvicidal fish. Pyrethrum spray. Oiling with a light oil.	Remove, empty and/or destroy useless containers, shells, cans, gourds, etc. Empty water out of boats periodically. Cresylic acid larvicide. Oiling.

USE EVERYWHERE AND ALWAYS—Intelligent selection of sites for dwellings, barracks, and camps, to avoid vicinity of Anopheles breeding areas. Avoid also, if possible, proximity to native villages or houses. Effectively screen quarters if possible; otherwise, use bed nets.

SECTION III.

MALARIA CONTROL

Malaria has been termed the most important of all human diseases. It is distributed almost universally throughout the warmer regions of the world and afflicts a large proportion of the world population each year. It is particularly important in military medicine because the necessities of war often require the rapid shifting of large groups of people and the penetration of highly malarious areas. Unless adequate measures are taken for malaria control, the services of an essential fighting unit may be lost through the ravages of this disease.

Under normal circumstances, malaria control operations would not be initiated without previous investigative studies. However, the control of malaria under military conditions often demands procedures quite different from those recommended in normal times. No method known to possess a fair degree of usefulness should be overlooked. Procedures must be started immediately and must often be greatly modified as work progresses. Resourcefulness and ability to carry on with limited and improvised equipment are essential.

Under combat conditions, the control of malaria is almost solely dependent upon the individual. Troops must previously have been educated in regard to the malaria danger and thoroughly trained in "malaria discipline." The individual must utilize the protection from mosquitoes afforded by clothing, repellents, bed and head nets, and the freon-pyrethrum bomb.

When time and the military situation permit, careful investigation should precede campsite selection. A routine adult spraying program should be instituted. If the camp is to be permanent or semipermanent, the entomologist should immediately begin a survey of the camp and the area a mile around it. As anopheline breeding places are located, crews should be detailed to begin immediate control. Maps should be prepared as early as possible as an aid in systematizing the work.

MALARIA SURVEYS

As time permits, a more detailed study of the local malaria problem should be initiated to make possible the development of a more efficient and scientific control program. Basic facts about the geographic and seasonal incidence and distribution of malaria should be investigated. Information of this nature will enable a unit to take full advantage of non-malarious areas or seasons in an endemic theater of operations. To the greatest extent possible, the written records of an area should be explored beforehand so that full advantage may be taken of peacetime surveys.

Oftentimes there is no information available as to the incidence and distribution of malaria in a given theater of operations. Thus it is necessary for the malaria control officer to determine as soon as possible if malaria is endemic in the particular area. Until this fact is ascertained it <u>must be assumed</u> that malaria is present and all precautions taken.

MALARIA SURVEYS

In a malaria survey, an attempt is made to find out (1) whether or not malaria is endemic in the area, to what extent it is present and its distribution; and (2) what anopheline mosquitoes are present in the area and their habits and habitats.

INCIDENCE SURVEY

Valuable information about the incidence and distribution of malaria can be obtained in a few hours by an examination of local children between the ages of two and fourteen for signs of splenic enlargement. By cooperating with the chief official of a village and by using candies, beads, pennies, or other suitable rewards, it is possible to attract nearly all of the children in a native community to a central place. This will permit palpation for splenic enlargement and even the taking of blood smears. Malarial infections invariably produce some degree of splenic enlargement which may persist when the infection becomes chronic, particularly in inadequately treated persons. While other infections may also produce acute enlargement of the spleen, these subside quickly. Therefore, in most communities where other acute infections have not recently been epidemic, the presence of any number of persons with splenic enlargement may be significant from a malarial standpoint. If enlargement is due to malaria, these persons will usually show a significantly higher proportion with parasites in their blood than will be found in those with normal spleens. Smears should be taken from each person with an enlarged spleen and from a certain proportion (every second, third, fourth) or all of those persons presenting negative spleens.

The examination for splenomegaly is preferably made with patients in the recumbent position with knees flexed and abdomen bared. The examiner, standing on the patient's right side, palpates lightly with the right hand which is held more or less at right angles to the costal margin. Two requisites are essential for successful examination: light pressure of the examiner with the hand flat upon the abdomen, and relaxation of the patient, associated on his part with full, deep, abdominal breathing. Thoracic breathing with tense muscles can prevent the detection of a spleen which otherwise would be readily palpated below the costal margin.

The record should state the relative position of the lower border of the enlarged spleen. For this purpose Boyd's classification of splenic enlargement has been found practical. His classification divides enlarged spleens into five groups, namely those palpable on deep inspiration (P.D.I.), and numbers 1,2,3, and 4. The ascending numbers indicate progressive degrees of enlargement, varying from No. 1 at the costal margin on normal inspiration to No. 4, which extends below the umbilicus. No. 2 enlargement extends to any point lying from the costal margin to half-way to the umbilicus, and No. 3 from the former limit to the umbilicus.

Malaria surveys are usually employed in two groups of people:

1. On native groups, in which case both blood and spleen will be examined.

2. On military personnel, in which case spleen examination may or may not be included; but history of malaria exposure, malaria attacks and suppressive treatment will be important.

MALARIA SURVEYS

An analysis of the survey is made by tabulating the results from the log or data sheets. Data and tables may be more condensed or more detailed than the examples given.

1. Data Sheet or Log, Native Survey.

Date________________ Village or Town________________________
Personnel making the survey____________________________________
Data pertinent to the group, the environment or circumstances____________

Number	Name	Age	Sex	Spleen	Blood Parasites	
1.	John Doe	8	M	#2	P. f +++	Gamet. +
2.	Mary Doe	14	F	PDI	P. v +	Gamet. -
3.						

2. Data Sheet or Log, Military Survey.

Date________________ Unit and Organization______________________
Personnel making the survey____________________________________
Data pertinent to the group____________________________________

Number	Name	(Rate	Age)	Malaria Attacks	Suppressive Rx	Blood
A-1	Henderson, J.R.	Pfc	22	Two	Atabrine Reg.	P. v +
A-2	Grace, G.O.	Pvt	20	None	Atabrine Irreg.	-
A-3						

Note: Rate and age may not be very important except for purposes of identification, but analysis may show a difference in incidence due to differences in exposure (officers and enlisted men). When possible the dates of each attack of malaria should be shown. The dose of suppressive drug, how long taken, when last taken and regularity of taking may be of importance.

ANOPHELINE SURVEY

A survey of the anopheline fauna is important even though malaria is not endemic in a particular area. Carriers may be brought into the area with our own forces; and if anophelines capable of transmitting the malaria parasite are abundant, a cycle of transmission may be established. The following sequence is suggested for an anopheline survey. It is intended for use in an area where malaria is endemic. Certain modifications may be necessary in areas where malaria is absent, even though the anophelines capable of transmission are present.

(1) Determine the species of anophelines present in the area.
(2) Distinguish the man-feeding from the animal-feeding species.
(3) Determine which species are the important local vectors of malaria.
(4) Determine the water types producing the vector.
(5) Determine the relative abundance of adults and larvae of different species.
(6) Study the bionomics of the principal vectors.
(7) Determine the seasonal abundance of the vector, especially in relation to rainfall and temperature.
(8) Prepare suitable maps showing breeding areas in relation to actual and potential campsites, native villages or other foci of malaria infection.
(9) Establish a routine system for checking larval and adult populations in order to evaluate the control program.

The various anophelines present in an area can be determined by the collection and identification of adults and larvae wherever they can be found. Adults may be obtained through nocturnal bite-catches, the use of traps, and from daytime resting places or capture stations. These latter include corners inside and under houses, privies, stables, native huts, or other shelters; tree holes; culverts and undersides of bridges; or other resting places peculiar to the local anopheline fauna.

FIG. 58. Collection of adult mosquitoes from a natural resting place.

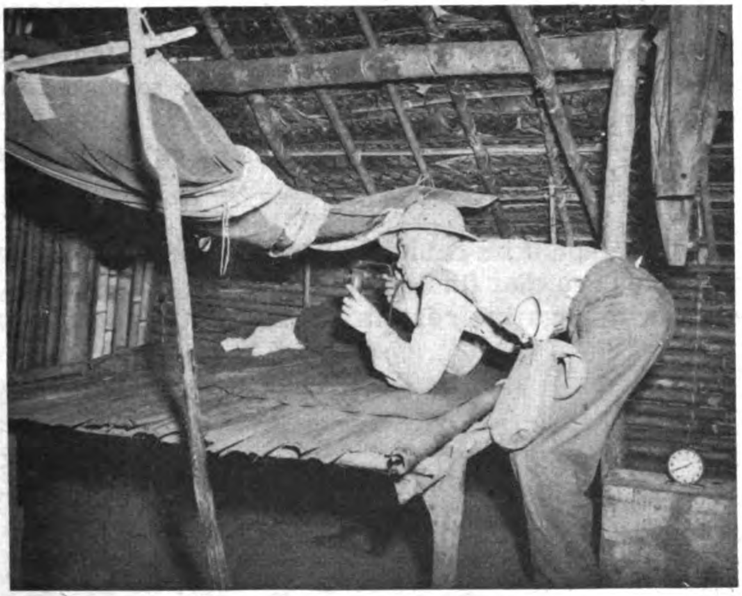


FIG. 59. Collection of anophelines in native hut.

Bait traps are merely small screened animal sheds built so that mosquitoes can make their way in through a small slit but will be unable to get out again. A domestic animal or even man may be confined within the cage at night. In the morning, the animal is removed and the entrapped mosquitoes collected. It must be remembered that individuals as well as species will vary in their relative attractiveness to anophelines. Such bait traps may be of particular value in determining the densities of those anopheline species that do not remain in accessible shelters during the day.

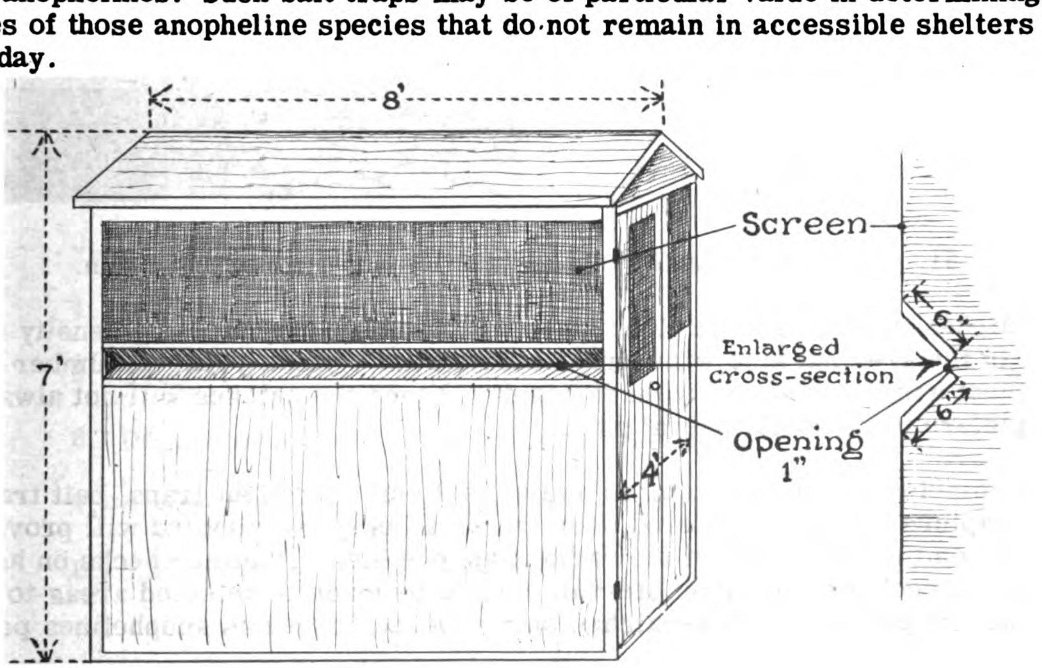


FIG. 60. The Magoon type bait trap.

Negative findings with bait traps should not be accepted as final evidence of the absence of adult anophelines. Animal baited traps may be expected to attract and capture a relatively large number of zoophilous and a relatively small number of anthropophilous mosquitoes. This is an important consideration in interpreting results.

If light traps are used, it should be remembered that the degree of attraction to light also varies with species, so that findings negative for anophelines should be accepted only in conjunction with negative results from other collecting procedures.

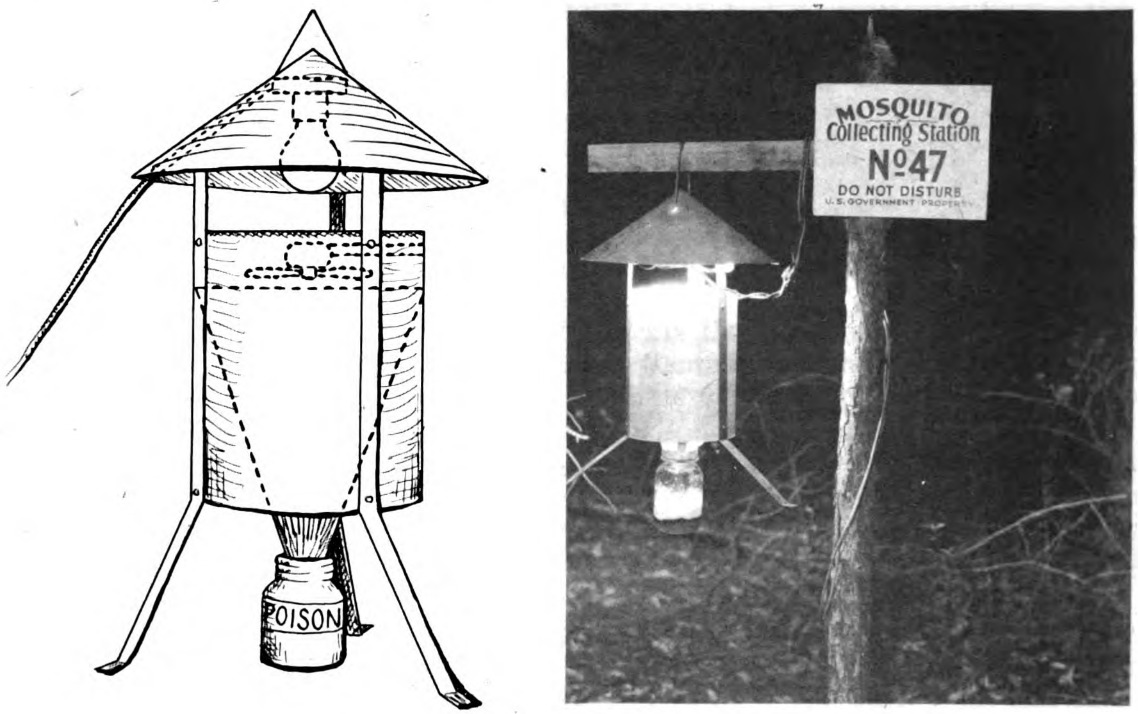


FIG. 61. Light trap. Detail of construction and trap in operation.

Catches in both bait and light traps will vary not only with the density of mosquitoes in the area but also with temperature, wind, humidity, and a number of other factors that are not constant from day to day; hence the catches will not always give a true picture of mosquito prevalence.

A combination of bite-catches and collections from light traps, bait traps, and routine capture stations scattered over the area being investigated will provide valuable data on the abundance of the various anophelines. Routine checks on adult densities at weekly or ten-day intervals should be made in selected areas to check on the control program. Bite-catches should be expressed as anophelines per man-hour.

Records pertaining to adult anopheline captures should include:

1. Locality.
2. Date and time of collection.
3. Type of station, diurnal or nocturnal.
4. Weather conditions.
5. Names of species and numbers of males and females.
6. Number of collectors and time spent on bite-catches.

Special attention should be given to anophelines captured in or near habitations and those feeding on man. Anophelines captured under these conditions are those most likely to be the malaria transmitters. Such specimens, especially blooded females, can be dissected to determine the presence of oocysts on the stomach wall or sporozoites in the salivary glands. This evidence is important in incriminating the local vector. The dissection procedure is outlined in the discussion of entomological techniques in Section IV.

Mosquito larvae are usually found at the surface of the water in aquatic vegetation, mats of algae, or floating debris, in the grassy margins of streams and ponds, or in other protected places. All actual and potential anopheline breeding places should be carefully surveyed for the presence of larvae. The following data should be noted in the records:

1. Location of breeding area.
2. Date of collection.
3. Type of water collection.
4. Degree of exposure to the sun.
5. Type of aquatic vegetation.
6. Degree of salinity, if in brackish water.
7. Average number of larvae per dip (ten dips).
8. Species of anophelines collected.

FIG. 62. Dipping for anopheline larvae.

From such larval surveys, the important breeding places can be determined--streams, ponds, lakes, swamps, marshes, salt marshes, rain pools, wells, road ruts, springs, seepage areas, rice fields, taro gardens, irrigation ditches, watering troughs, brackish and fresh water lagoons, water-holding plants, or artificial containers. Once the important anopheline vector is determined and its larval breeding places catalogued, the habits of the adult should be studied. Its flight range, time of biting, length of life cycle, seasonal abundance, and other important biological characteristics should be investigated. Since only one or at most a very few anophelines are ever important malaria vectors in any one area, malaria can be controlled most efficiently by attacking the specific vector in its characteristic breeding places. This type of attack is termed species sanitation and is based on the idea that all control measures can be adjusted and limited to the particular offending anopheline in the area being controlled.

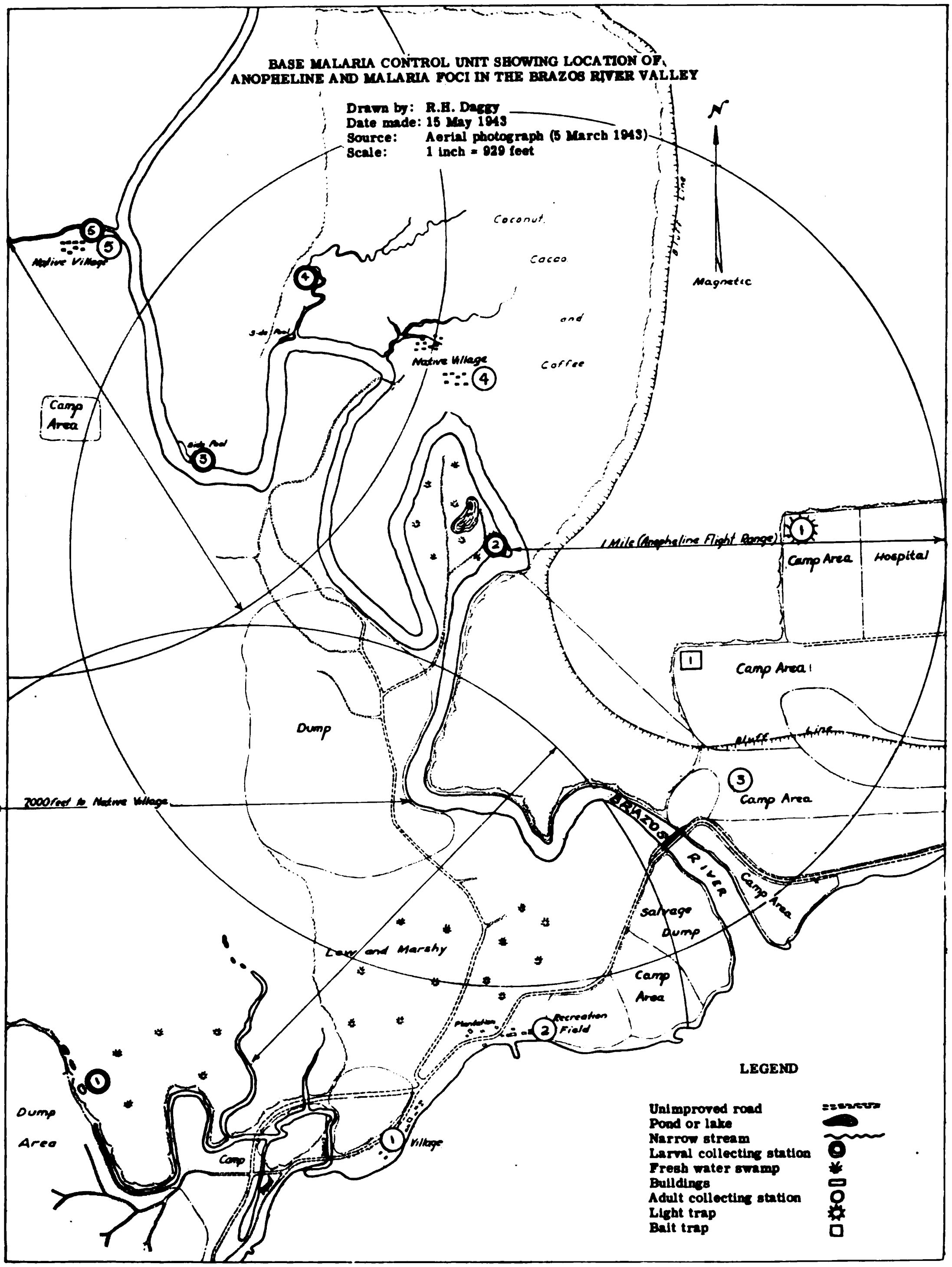


FIG. 63. Sketch map showing locations of adult capture stations and larval breeding areas. For information on the preparation of maps, see the discussion on Surveying and Mapping.

MALARIA CONTROL

CONTROL PROCEDURES

The intelligent control of malaria presupposes a firm grasp of the fundamental features of the biology of the disease. For this reason, the malaria transmission cycle, especially as it relates to control measures, is briefly reviewed.

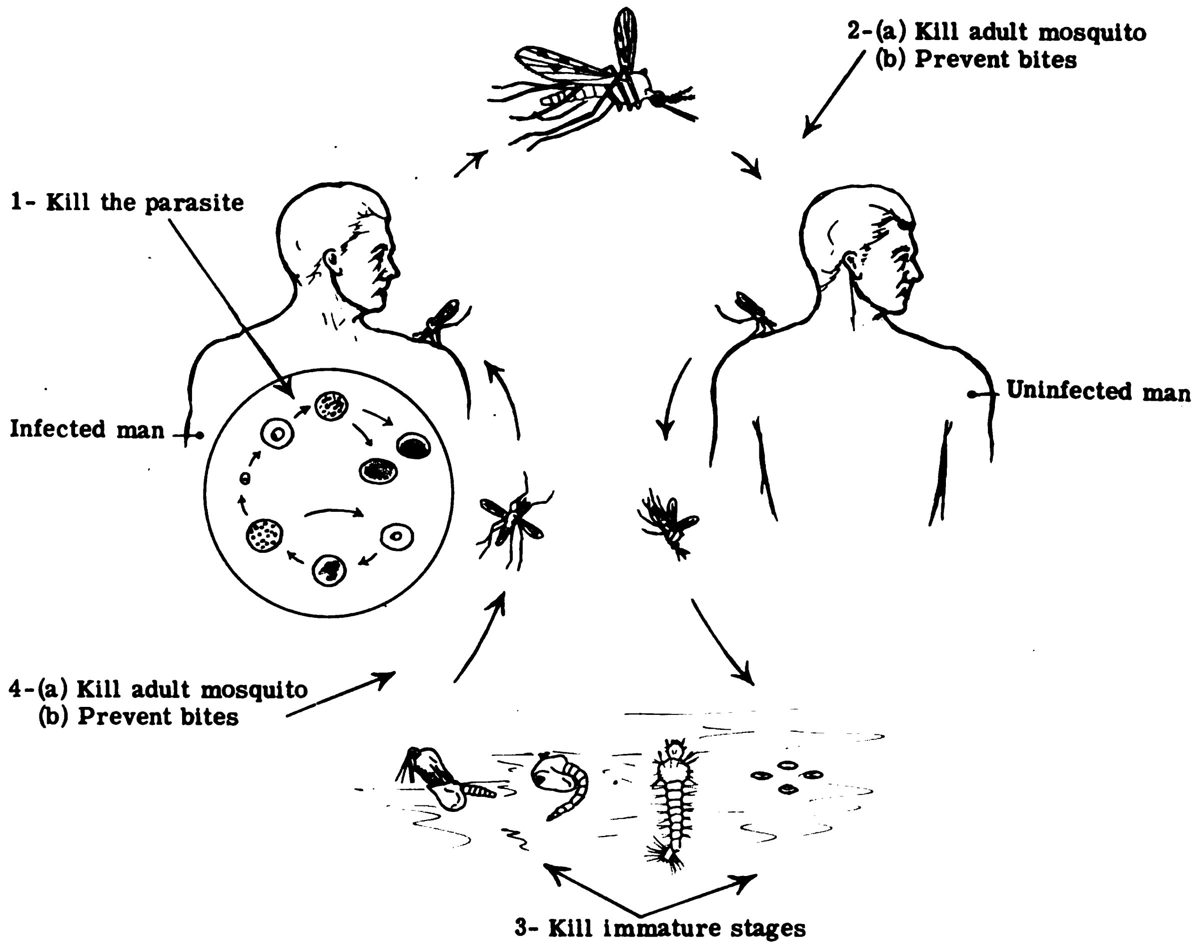


FIG. 64. The transmission cycle and control of malaria.

To transmit malaria, the anopheline mosquito must first bite an infected person and ingest the malaria parasites in the form (gametocytes) infective to the mosquito; the mosquito must support these parasites within her body until they reach the stage in their development (sporozoites in the salivary glands) that is infective to man; the mosquito must then inject these sporozoites into a person who, in turn, must develop gametocytes in his blood before a second cycle of transmission can begin.

CONTROL PROCEDURES

The existence of human malaria in any area in the world, therefore, is possible only through the close biological interrelationship of three animals: the plasmodium, certain female anopheline mosquitoes, and man. The removal of any one of these three from this partnership, whether by death or withdrawal behind a screen barrier, will interrupt the essential malaria transmission cycle. Practical efforts in this direction may be grouped under the following three headings:

1. Eliminating the parasite in man.
2. Eliminating the mosquito vector.
3. Preventing mosquitoes from biting man.

Our present techniques and facilities are usually inadequate to effect the control of endemic malaria through the exclusive use of any one of the three procedures, but an appreciable reduction of the disease by the simultaneous use of two or three of the procedures has been demonstrated in many parts of the world. In practical malaria control at the present time, it is generally desirable to use all three procedures concurrently.

ELIMINATING THE PARASITE IN MAN

The control of malaria exclusively through the drug treatment of man has not proven satisfactory. Perhaps the main reason for this is the fact that no chemical or biological prophylactic is available which will destroy the parasite as it enters the human body, nor is a therapeutic agent available which can be relied upon to eliminate the vegetative stages of the parasites and the gametocytes from the body. As a result, both new infections and recurrences continue to form a parasite reservoir for the subsequent infection of additional mosquitoes.

This does not mean that prompt treatment of malaria cases is not of assistance in reducing the malaria rate in an area, but it does mean that the exclusive dependence upon treatment with present drugs is inadvisable. Details of the treatment of man, its usefulness and limitations, will be found in the Naval Medical School manual, "Notes on Tropical and Exotic Diseases of Naval Importance."

CONTROL PROCEDURES

ELIMINATING THE MOSQUITO VECTOR

Except in rather unusual situations, measures directed against the mosquito vector have an important place in malaria control programs. Generally, it is advisable to attack both the winged adults and the immature aquatic stages.

KILLING ADULT MOSQUITOES

The hand destruction of adult mosquitoes is a method of limited usefulness, but has a definite place in many control programs. The crushing of adults that have found their way into bednets is a necessary procedure in the effective use of these nets. In larger spaces, in the absence of proper sprays, swatters may be used or cups containing a small amount of kerosene and fastened on the ends of short poles may be clapped over mosquitoes resting on the ceiling.

The routine spraying of quarters or other buildings that are occupied at night will kill many adult mosquitoes. In mosquito-proofed structures, spraying just before retiring may suffice to protect the occupants for the night. In open buildings or tents, spraying may kill very few adults of those species that leave the enclosure immediately after feeding, but may kill a substantial number of the females of species that rest for a time before or after feeding.

In some situations it has also been found effective to spray the anophelines' daytime resting places - cool, shady tree holes, culverts, caves, and nearby native huts. The spraying of native huts has special significance, since a considerable percentage of the females found resting there may be infected with malaria parasites. When spraying of adults is made a part of the malaria control program, it should be done on a regular schedule and by personnel who understand its significance and the techniques involved.

Particular efforts should be taken to prevent anopheline mosquitoes from spreading to new areas along paths of transportation. Wherever such hazards exist, Navy directives require that all planes be sprayed just before taking off from an infested area and just after arriving at an uninfested area. Surface ships should be sprayed enroute, just after leaving port and just before arriving at destination.

Pyrethrum sprays and aerosols are the materials most generally used in the destruction of adult mosquitoes. Spray material is supplied in two forms: a twenty-to-one concentrate (extract of twenty pounds of pyrethrum flowers in one gallon of solvent and containing not less than 75 grams of total pyrethrins per gallon) and a prepared ready-to-use spray. The former is diluted with kerosene (preferably an odorless grade), one to fourteen parts by volume before using. Sprays are applied

with the common hand sprayer or, for large volumes, a power-driven paint sprayer may be used. Since this spray is a contact insecticide, special care must be taken to insure that the spray reaches all likely resting places of mosquitoes, such as darkened corners, lockers, clothes racks, and under bunks. One-half ounce will treat 1,000 cubic feet of closed space.

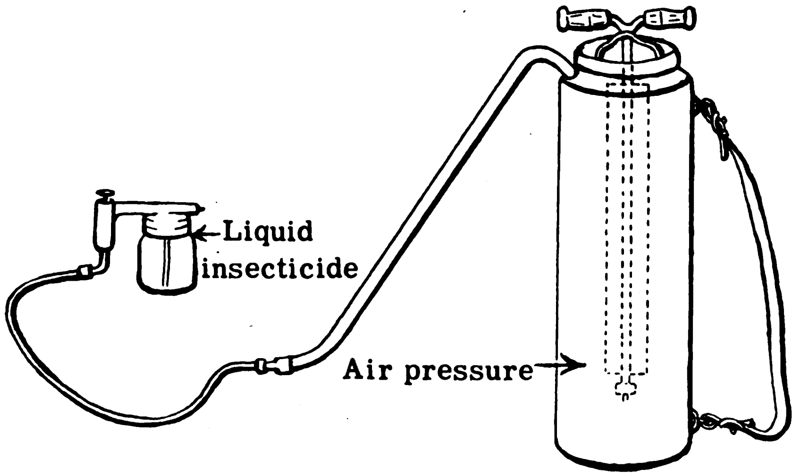


FIG. 65. Sprayer made from paint gun and cylindrical spray-tank.

Pyrethrum deteriorates rapidly when exposed to air or sunlight. All stocks of sprays should be kept tightly closed and out of the sun. If stored properly, pyrethrum sprays will keep for over a year. If they fail to kill in three minutes or less all adult mosquitoes with which they come in contact, they have deteriorated beyond usefulness and should be discarded. Aerosols may also employ pyrethrum as the killing agent. Sesame oil is included as synergist or activator, and freon (a nontoxic chemical commonly used as a refrigerant) as the dispersing agent. Pyrethrum aerosol is much more effective than the ordinary coarse spray and will disperse in a closed space quite readily. One pound is sufficient to treat 150,000 cubic feet of closed space. Pyrethrum aerosol is supplied in one-, two-, and five-pound cylinders. They should be stored away from heat.

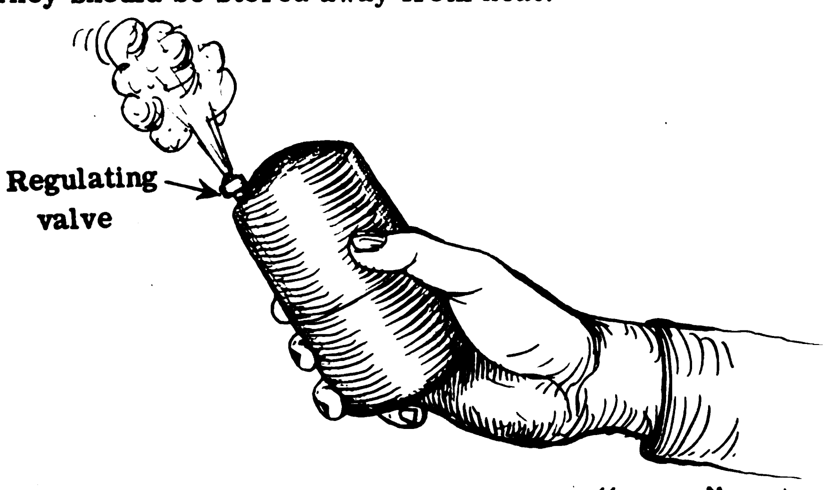


FIG. 66. Pyrethrum-aerosol "bomb."

KILLING ADULT MOSQUITOES

DDT (dichloro-diphenyl-trichloro-ethane) is a newly developed insecticide, the spray deposit of which is highly toxic to any mosquito that lights on it. It is very effective as a simple contact poison, but its outstanding characteristic is the toxic action of the spray residue, which evidently exerts its effect through the feet of the insect. As a simple contact insecticide, DDT may be applied either in a kerosene solution, in an aqueous emulsion, or in an aerosol. The killing of adult mosquitoes in critical or combat areas with a fine mist or aerosol is one of DDT's greatest possibilities, but no recommendations have as yet been formulated. Spray residue coatings may be applied as oil solutions or as emulsions with a knapsack sprayer, adjusting the nozzle to a fine spray, but not to a mist. Aerosols should not ordinarily be used in applying DDT residues. DDT can be used on the inside of barracks, tents, latrines, dugouts, mess halls, under bridges and in any resting places for mosquitoes within the campsite. Particular attention should be paid to the darker places, such as under beds, behind objects, and in corners. If screens are present, they also should be treated, preferably by painting, since spraying is likely to result in excessive waste. The many mosquitoes that land on screens in their attempts to enter buildings are thereby exposed to the insecticide. The most economical rate of application of DDT has not been determined, but dosages of 50 to 200 milligrams per square foot of surface areas are suggested. This represents a deposit of one to four cubic centimeters of five per cent spray solution per square foot, or about one quart per 100 to 400 square feet. At this rate of application, a large barrack would require approximately one to four gallons of the five per cent spray. The preparation of solutions and emulsions is described in the following section on the killing of the aquatic stages.

Since mosquitoes frequently acquire malaria parasites from natives, the control or reduction of the disease among natives may prevent infection of troops. Where natives in nearby villages exhibit a high incidence of malaria and where it is feasible to apply treatment to their habitations, the same general procedure in the application of the residue spray can be followed as suggested for campsites.

Although the application of spray films to building surfaces involves considerable initial material and labor, results indicate that single applications of DDT will remain effective against mosquitoes entering the treated buildings for one and one-half to three months, and perhaps longer. During the interim, the deposit will kill many mosquitoes before they have an opportunity to take their infecting blood meal or to rear their load of parasites to maturity.

ELIMINATING THE MOSQUITO VECTOR

CONTROL OF THE AQUATIC STAGES

Since the aquatic stages of mosquitoes are concentrated in specific water areas, they are generally more easily found and destroyed than are adults. Because of this fact, more thorough and permanent measures are generally possible against the aquatic stages than against the adults.

CHEMICAL CONTROL

The chemical control of aquatic stages is accomplished by means of toxic oils or stomach poisons. These measures are strictly temporary and must be repeated at frequent intervals throughout the breeding season. However, they are important supporting measures where permanent drainage or filling has not yet been completed.

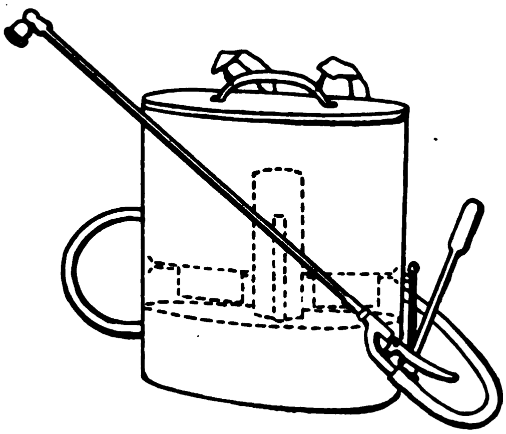
<u>Petroleum oils</u> applied to the water surface kill in one or more of the following ways: by penetration of the breathing tubes by toxic fumes, by poisoning due to toxic water-soluble fractions of the oil, by suffocation resulting from mechanical blockage of the respiratory tubes, or by reduction in the surface tension of the water to such a point that the larvae cannot hang from the surface. Not all petroleum oils are equally effective. A cheap product of suitable toxicity, viscosity and spreading qualities is required. When sprayed on the surface of the water, it should form a thin, uniform, and persistent film. The best larvicidal oils will kill in less than thirty minutes. <u>#2 Diesel fuel oil</u> is highly toxic to larvae and pupae, and has the additional advantage of being practically non-toxic to vegetation. Neither gasoline nor any other petroleum oil should be used on potable waters in metal containers because small amounts of the oil are adsorbed on the sides and give an unpleasant taste to all water subsequently stored.

<u>Waste crankcase oil</u> is sometimes used as a larvicide but is not very satisfactory. It has a low toxicity, it does not spread well, and it must be strained to remove sediment that would clog the sprayer. When Diesel oil is not available, crankcase oil (1 part) mixed with kerosene (3 parts) can be substituted. Straight crankcase oil can be used in abandoned wells or similar water collections when filling or drainage is not practical. In such cases, a thick, continuous layer, requiring only a few applications during a whole year, may be poured on. Ordinarily, oil should be applied only to those water surfaces in which experience would indicate that breeding is likely to occur. Larvae are rarely present in unimpeded, swiftly moving currents or in the deeper parts of ponds devoid of surface vegetation or flotage.

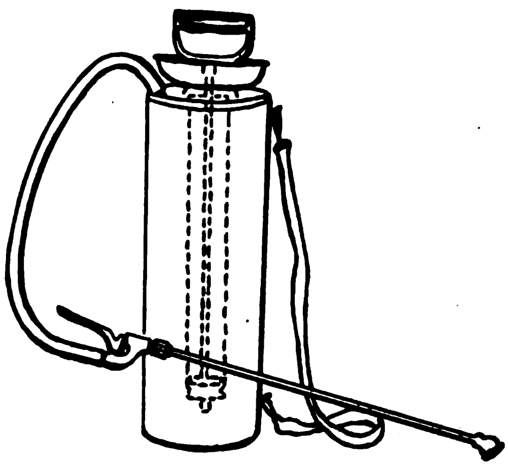
If an application is effective, no further breeding will take place until the oil film dissipates. Generally, from seven to twelve days will elapse between oiling and the next appearance of fully developed pupae. To allow a margin of safety, malaria control schedules usually call for weekly applications. When the anopheline population has been reduced to a point where breeding is not continuous or

when cooler weather appreciably retards larval development, oiling may be limited to those scattered spots where larvae or pupae are actually found. If this "spot-oiling" is done, it should be accompanied by regular and thorough inspections of all possible breeding places. In all cases, routine post-treatment inspections should be made within twenty-four to forty-eight hours to determine the effectiveness and thoroughness of the oiling operation.

The amount of oil spread should be sufficient to form a continuous, thin, metallic-colored film on the water surface. A lesser amount will not result in a satisfactory kill, and a greater amount will not increase the kill and is a waste of time and oil. The rate of application varies from ten to twenty gallons per acre of breeding surface. However, wind, temperature, flotage, and vegetation affect the application so greatly that the proper amount of oil to be used in any given case must be determined by experience. The usual method of applying oil to a water surface is with a spray can. Two types are now available: the knapsack sprayer and the cylindrical sprayer.



A



B

FIG. 67. Hand-operated sprayers. A. Knapsack type. B. Cylindrical type.

The knapsack sprayer has a capacity of four to five gallons and is carried on the back by means of shoulder straps. The pump must be operated continuously during spraying. The cylindrical sprayer has a three-gallon capacity, and is carried at the side by a sling shoulder strap; the pump is operated only when necessary to build up the air pressure in the cylinder. The cylinder type is listed as: "apparatus, decontaminating, three gallons," in the general schedule of supplies. With either type, a man can distribute about thirty to forty gallons of oil per day under average conditions.

If sprayers are not available, oil may be applied to small collections of water by means of oil-soaked brooms or mops, oil-soaked waste or rags tied to a stick, or oil-saturated sawdust scattered over the water. An ordinary watering pot can also be used. Where a breeding area is too large to be oiled by hand, power sprayers may be employed to advantage.

One of the most serviceable pumps is the gasoline operated portable water pump. A one-quarter inch pipe, fitted with an adjustable valve, is tapped into the suction line and connected by hose to an oil container. The flow of water past the tap sucks oil into the pressure stream, with which it is carried out over the breeding place. Power operated decontamination sprayers can also be used. In this case, oil can be put directly into the water of the spray tank instead of being introduced into the suction line, provided an emulsifying agent such as casein or albumin is available. Either of these units can be mounted on a truck or boat. Airplanes have been used to distribute oils over extensive breeding areas, but this method is of limited practicability because of the weight of the oil.

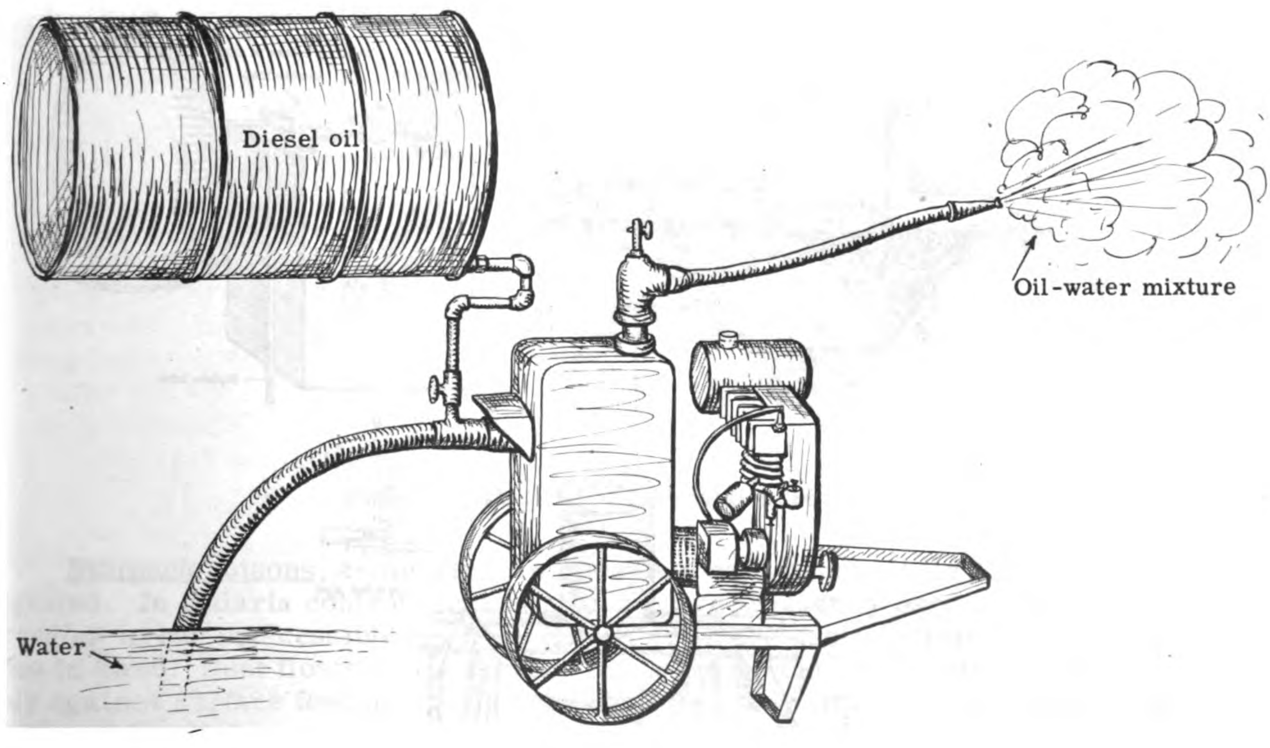


FIG. 68. Portable water pump adapted for spraying oil.

It is essential that oil sprayers have their hoses made of oil-resistant synthetic rubber. A stock of replacement parts (hose, gaskets, nozzles, and straps) should be kept on hand and all sprayers maintained in good repair. Strip graphite

mechanical packing (Garlock 5354) can be cut in proper lengths for replacing worn gaskets. Three-eights inch stripping is used in the decontamination type sprayer, while one-fourth inch stripping is used in the Robbins knapsack type sprayer.

Continuous oilers are sometimes used in streams or in permanent small bodies of standing water that are not easily accessible for hand spraying. <u>Drip oilers</u> can be set up over streams or ditches where the water surface flows smoothly and where the channel is fairly free of vegetation or obstructions so that the oil will be carried evenly into eddies and other places where slow water movement permits breeding. The container should be placed three or four feet above the stream so that the drops of oil will spread well on striking the surface. The rate of drip should be regulated according to the width and velocity of the stream and the amount of obstruction to flow. For a slow-flowing stream one foot wide, ten to twenty drops per minute should be adequate. A modification of the usual drip-can has been developed in which the air-intake above the oil is regulated by a needle valve. The air-intake controls the amount of oil released through a siphon and avoids the clogging which so frequently disrupts the flow in other types of drip oilers. A bubble trap prevents breaking of the siphon column by froth. Breaking of the column by sudden contraction due to heating and cooling may be prevented by shading the drip can.

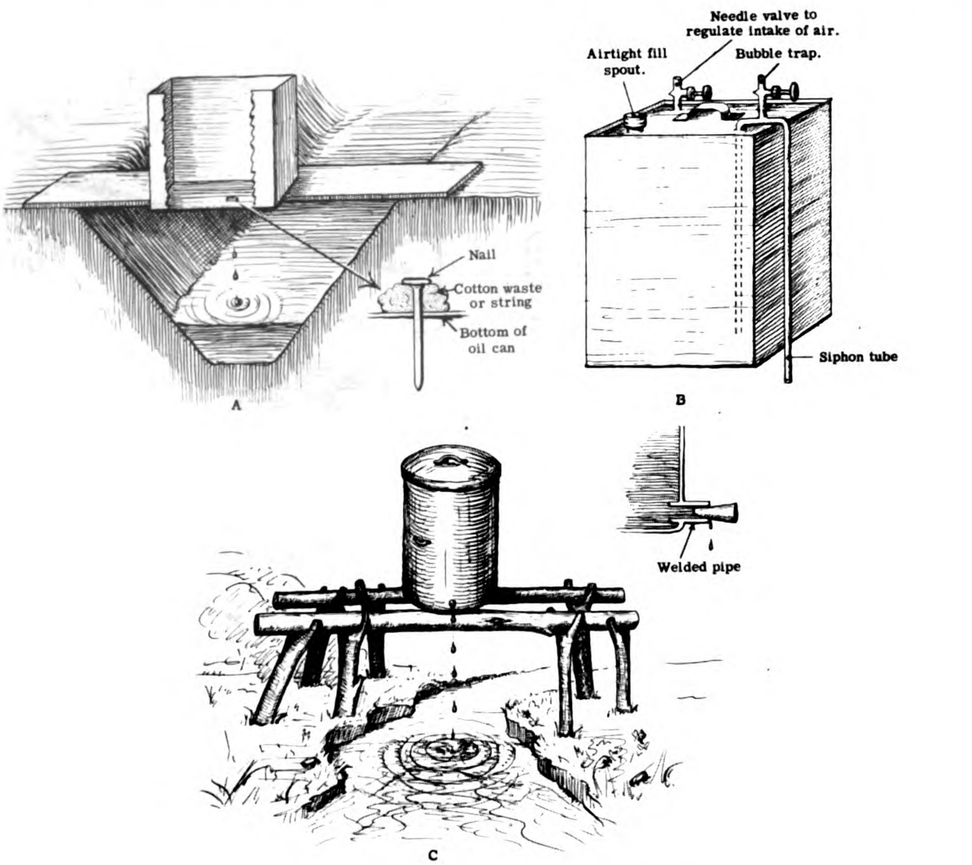


FIG. 69. A. Simple oil drip. B. Siphon drip can. C. Drip can in position.

Bag oilers can be used either in streams or in standing water of small area. They are made by filling burlap bags with sawdust, rags, or cotton waste previously soaked in oil. A bag may be anchored to float or may be submerged by weighting with rocks. Large pickle jugs or other containers may be fitted with two-hole lids, filled with oil and submerged in breeding waters. When the jug is tilted from the upright position, the water enters the lower hole in the lid and oil escapes slowly from the upper hole. A wick can be placed in the exit hole to reduce the oil flow, especially when DDT in oil is used.

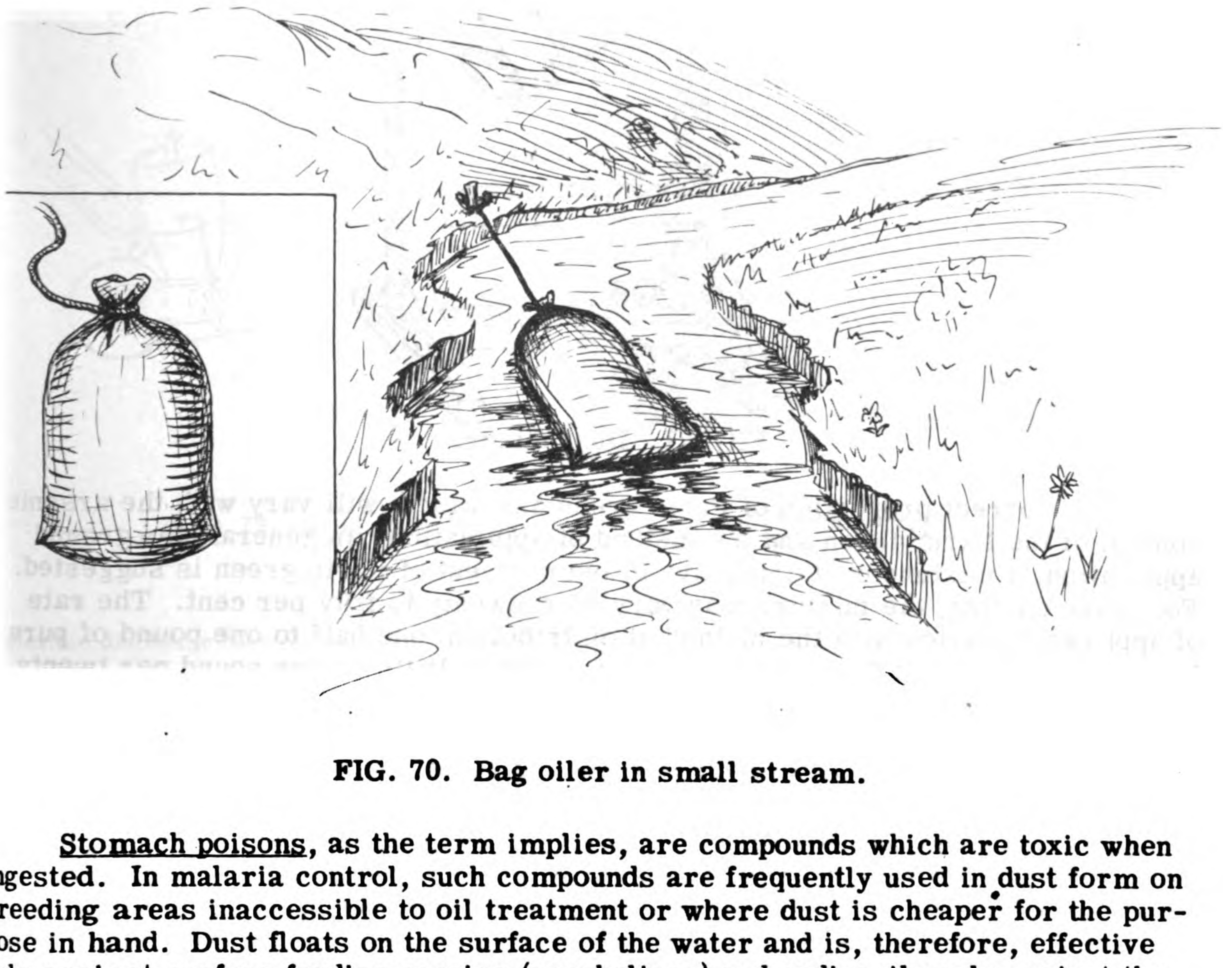


FIG. 70. Bag oiler in small stream.

Stomach poisons, as the term implies, are compounds which are toxic when ingested. In malaria control, such compounds are frequently used in dust form on breeding areas inaccessible to oil treatment or where dust is cheaper for the purpose in hand. Dust floats on the surface of the water and is, therefore, effective only against surface feeding species (anophelines) and ordinarily only against the third and fourth instar larvae.

The most satisfactory stomach poison is Paris green (copper aceto-arsenite). It should have the following specifications: color--emerald green; particle size--pass 300 mesh screen; arsenic content--not less than fifty per cent arsenious oxide; solubility--not over three per cent. When Paris green is unobtainable, lead arsenate, cryolite, phenothiazine or other stomach poisons of low solubility, although less

satisfactory, may be substituted. Paris green powder is usually mixed with a dry diluent for field use. Any finely divided, inert material may be used, such as road dust, hydrated lime, fuller's earth, talc (soapstone), flour, or cement. The choice is governed primarily by availability and cost. The poison and diluent may be mixed with a shovel or tossed about together in a dry oil drum mounted eccentrically on an axle.

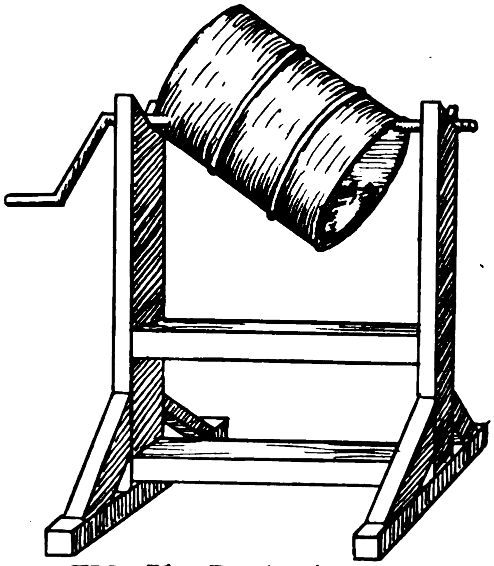


FIG. 71. Dust mixer.

The correct proportion of Paris green and diluent will vary with the arsenic content of the Paris green and the method of application. In general, for ground application, a mixture containing five to ten per cent of Paris green is suggested. For plane dusting, the mixture may vary from twenty to fifty per cent. The rate of application varies with the method of distribution: one half to one pound of pure Paris green per acre for ground application and as little as one pound per twenty acres for plane dusting. These figures are only approximations. Mixtures used should be tested both in the laboratory and in the field to determine the best strength and rate of application for the existing conditions.

In applying dusts, the object is to disperse the poisonous material in a cloud above the breeding area so that particles will settle on the water surface. To be successful, application must be made at a time when wind and convection currents over the water are not sufficient to dissipate the dust cloud before it can settle. Application from the ground is less limited by wind than is plane dusting. In either case, however, a moderate drift of the dust cloud is helpful in giving a more even distribution of the poison and in carrying it to parts of the breeding area not otherwise readily accessible. Dusting should, therefore, be done to windward of the breeding area. Better results will also be obtained if the vegetation is not covered with dew. The film of Paris green on the water is readily broken up by rain, wind, and waves. For maximum kill, the film should persist about three hours. Since a stomach poison kills only the older larvae, applications must theoretically be repeated at slightly more frequent intervals than when oil is used. In practice, how-

ever, a weekly interval is generally used for dusting also. The mixture may be broadcast by hand in the manner of sowing grain, but this method is slow and wasteful of material. Rotary blowers are the most satisfactory for ground work. Hand operated dusters are commonly used to cover small areas. Under average conditions a man should dust from ten to twenty acres per day with this type of apparatus. A power duster mounted on a light truck or in a boat may be used for larger areas.

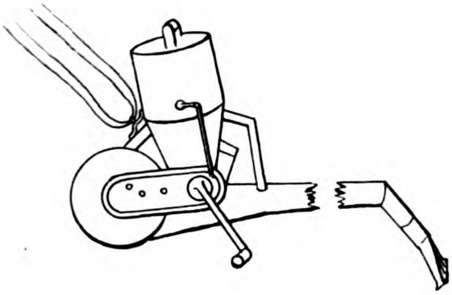


FIG. 72. Rotary hand duster. Diagram, and in operation.

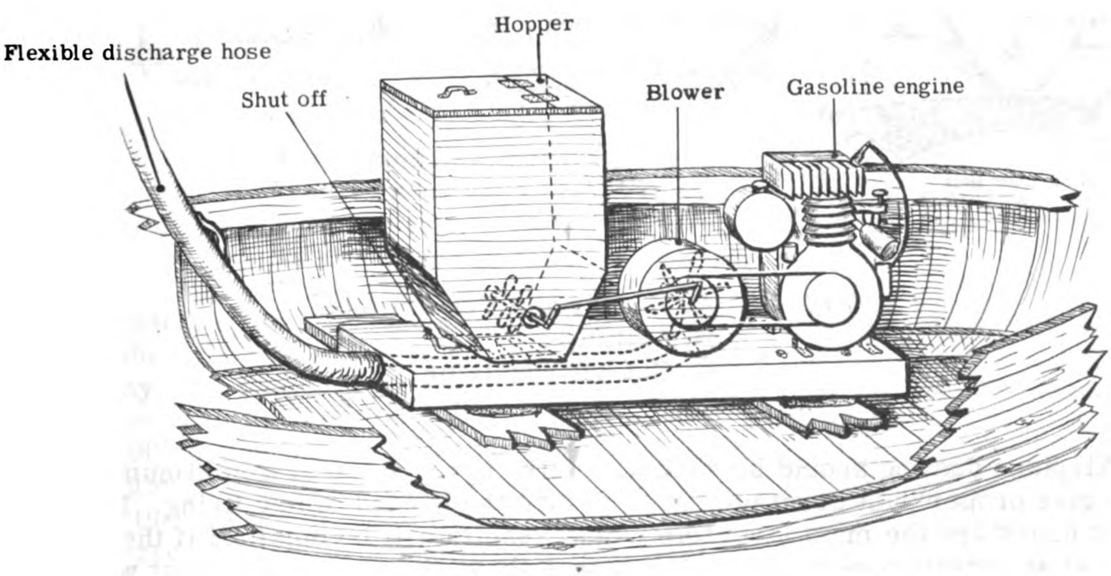


FIG. 73. Power duster in boat.

Airplane distribution is the most efficient for extensive areas, provided the terrain is suitable for low-level flying. An airplane, to be suitable for dusting, should have a comparatively low flying speed (80 to 100 mph.), great maneuverability, good load capacity (500 lbs. or more) and a tight fuselage to protect the operator from the insecticide. The dust mixture is usually carried in a metal hopper mounted in the cabin or cockpit and should be agitated mechanically to insure that it feeds down properly through the floor to the Venturi tube. A shut-off gate is built into the tube to control the flow of dust. The dust sucked into the Venturi tube is caught by the slip-stream and dispersed in a cloud behind the plane.

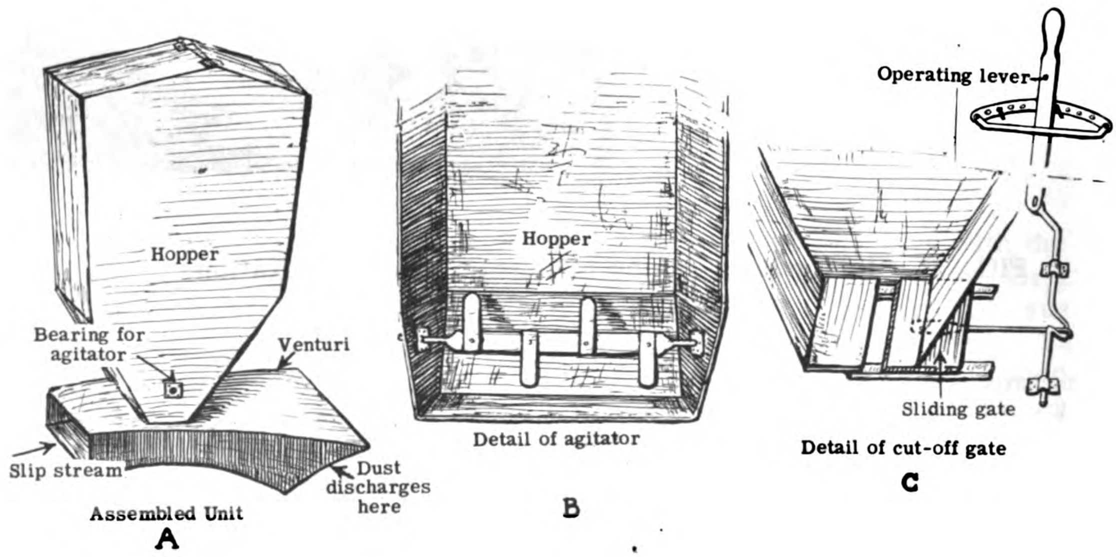


FIG. 74. A. Hopper and Venturi tube.
B. Agitator.
C. Cut-off regulator.

Airplane dusting should be done when air currents are at a minimum, not only to give proper dust coverage but to reduce the hazard of low flying. Early daylight hours are the most favorable. Best results will be obtained if the dusting is done at an elevation of twenty to thirty feet above the water. The dust will then blanket a strip 300 to 400 feet wide.

FIG. 75. Plane dusting.

Dustless mixtures of Paris green may be used where lack of equipment or other considerations make it necessary or desirable. A Paris green mixture that is more flotable than the dry dust may be prepared with the following ingredients:

Kerosene.	1 pint
Paris green	$\frac{1}{2}$ pint
Egg albumen (dry powdered)	1/4 teaspoon

(Egg albumen is not essential but makes a better emulsion. Where fresh eggs are available, 1/4 pint of a solution made by mixing five egg whites in a pint of water may be used in place of the powdered albumen).

The ingredients are thoroughly mixed and stored in bulk. To prepare for use, six teaspoonfuls (25 cc.) of the stock are mixed with five quarts of water and applied as a spray. By mixing only five quarts of spray at a time and by frequent agitation, the mixture can be kept from settling during use. Five quarts will cover approximately 500 square feet of breeding area. Paris green can also be mixed with moist sand or fine gravel in the proportions 1:100 by volume. Care must be exercised to regulate the amount of moisture so that the mixture can be strewn easily. It may be scattered by hand, even against a strong wind.

CHEMICAL CONTROL OF THE AQUATIC STAGES

As they are applied in malaria control, stomach poisons are not harmful to man, livestock, fish, or vegetation. The stock supplies, before application, can also be handled safely with the observance of a few simple precautions:

1. Do not store poisons where unauthorized people or livestock can gain access to them.
2. Mix dust in the open and use a dust mask.
3. Always dust to leeward to avoid drift.
4. After handling poisons, take a bath and wash your clothing.

DDT appears, from present indications, to be markedly superior to other previously known larvicides. It should not, however, be looked upon as a panacea for all the ills of a malaria-ridden world to the exclusion of other control practices of proven value; nor should DDT be applied carelessly and without due regard for its possible toxic effects on fish, other wild life, and on man. DDT in oil solution is particularly toxic to man and must be handled with care. For the present, at least, the supply of DDT is limited and it should be used as economically as possible.

Much remains to be done on the most effective and practical means of applying DDT. It may be used in three forms: in petroleum oils, in aqueous emulsions, and in dusts.

Petroleum oil solutions (five per cent) are prepared by dissolving two pounds of crystalline DDT in each five gallons of oil. The oil should be stirred, or the mixing barrel rolled, during the dissolving process which is slow and usually requires at least twenty-four hours. Diesel oil, kerosene, and crank-case oil (strained and diluted with kerosene) are recommended as solvents.

Because of the high toxicity of DDT for mosquito larvae, the amounts required for effective control are extremely small, about one or two quarts of five per cent oil solution per acre. This is only about 1/20 - 1/80 the amount of regular spray oil needed. The quantity of material needed per acre of water surface depends upon the amount of vegetation, the spreading power of the oil, and the method of application. Two quarts of five per cent DDT oil solution per acre gives a dosage of 0.2 pounds of DDT. This dosage will kill the larvae present, but it should not be expected to persist longer than seven to ten days. For residual toxicity, where wind and waves do not affect the oil film and where fish are not important, a dosage of one pound of DDT per acre should be used. Concentrations higher than one part of DDT per ten million parts of water will prove fatal to fish. In breeding areas less than one foot deep, applications heavier than two quarts of five per cent DDT per acre are likely to produce a fatal concentration.

The best method of application is with spray equipment. The spray-nozzle should have a disk orifice not larger than 50-60 gauge and should be adjusted down to as fine a spray as possible. The oil should be sprayed to obtain a maximum of wind drift. A swath of fifty to one hundred feet is suggested, although experimentally a DeVilbiss paint atomizer gave effective control for several hundred feet when the application was by wind drift and at the rate of one quart of solution per acre.

CHEMICAL CONTROL OF THE AQUATIC STAGES

An aqueous emulsion has been developed consisting of DDT twenty-five per cent, Triton X-100 (an emulsifier) seven per cent, and xylene (a solvent) sixty-eight per cent by weight. While this concentrate requires more materials and is more expensive than the simple oil solution, it has the advantage of being lighter to transport, since it can be diluted with water from breeding places in the field, one part with four parts of water, to produce the same five per cent concentration of DDT that is used in oil solutions. The emulsion is applied in the same way and in the same amounts per acre as the oil solution, but seems to be more effective against culicine mosquitoes than DDT in oils. The dilution can, of course, be altered to any strength needed. The suggested dosage will kill without producing marked residual effects; but since some residual action may result, the time for retreatment should be governed by results of dipping records. Dosages two or three times the above will prevent breeding for several weeks, but these heavy dosages have proven fatal to fish life. Therefore, where fish are valued, these higher concentrations are not recommended, nor are they economical in situations that are likely either to flood or to become dry.

No recommendations have as yet been made regarding the use of larvicidal sprays of DDT from airplanes. However, investigations have shown that oils containing DDT, and the emulsion of DDT-Triton-xylene, are highly effective when applied from a plane. Dosages as low as two quarts per acre of either spray containing ten per cent DDT have given effective control of adults as well as larvae in limited areas.

Dusts containing DDT are likely to be less effective against mosquito larvae than oil solutions or aqueous emulsions because of certain physical properties of the commercial DDT. The material is difficult to grind to the desired degree of fineness without the addition of diluent, and after grinding it has a tendency to pack or form lumps. A finely ground commercial product can be produced that contains ten per cent DDT. If such material is used, it is necessary to ship nine pounds of inert material for each pound of active ingredient. Furthermore, it is more difficult to mix dusts in the field than to prepare the spray solutions. Where these commercially prepared dusts can be supplied, however, they can be used effectively and can be applied readily with ordinary dusting equipment. DDT is from ten to one hundred times more toxic, weight for weight, than Paris green to larvae of *Anopheles quadrimaculatus.* For temporary control, a dust of one to five per cent is recommended, applied at the rate of one-tenth pound of DDT per acre. For a residual effect, ten pounds of ten per cent dust (one pound of DDT) per acre can be used.

ELIMINATING THE MOSQUITO VECTOR

MECHANICAL CONTROL OF THE AQUATIC STAGES

The mechanical control of mosquito larvae includes all those physical manipulations which are involved in eliminating or preventing the accumulation of mosquito-breeding waters. These manipulations include ditching, filling, pumping, and cleaning the edges of streams and ponds.

Drainage for malaria control - as opposed to agricultural, highway, or storm drainage - has as its purpose the removal of surface water with sufficient rapidity and completeness to prevent the maturation of the aquatic stages of anopheline mosquitoes. In malarious areas, these other types of drainage should always conform to malaria control standards insofar as completeness of drainage is concerned. Unfortunately, storm drains and irrigation systems are often constructed with no regard for residual pools which form good breeding places for anophelines. Pools such as remain in the bottoms of ditches are good examples of man-made malaria sources. Military construction of all kinds, especially roads and runways, should be so designed that man-made malaria will not result. Oftentimes careless construction may create malaria hazards far more serious than existed in the area prior to construction. Conversely, malaria control drainage has sometimes been found to improve the agricultural merits of the land to a degree that independently justifies the drainage.

Open ditches are the type of drain most commonly used in malaria control work. They are usually the quickest and cheapest to construct but require inspection and maintenance. The ideal malaria control ditch should remove water rapidly enough to prevent mosquito development, both in the area drained and in the ditch itself; should carry normal and peak volumes of water without scouring (erosion) or other damage; and should have flow characteristics that will prevent formation of silt deposits in the ditch bottom. This ideal ditch is not always realized but should be approached as closely as practical considerations will permit. The laying out of a good ditch requires a careful inspection of the area and good judgment.

The efficiency of a drainage ditch is governed primarily by the size and shape of the cross section and by the grade (slope). The area of the cross section should be great enough so that water will not overflow the banks at periods of peak flow, and the shape should be such that a minimum of water will remain in the bottom of the ditch when flow ceases. A narrow-bottomed ditch meets this last requirement best, the width of the bottom being determined, in actual practice, by the width of the digging tool. In wide-bottomed machine-dug ditches that do not carry water continuously, it is sometimes desirable to dig small hand ditches in the bottom to carry off residual water.

The side-slope of the ditch should be correlated with the character of the soil. If the sides are too steep, the banks will cave in; if too flat, excessive excavation is required in construction, and the area for a subsequent clogging growth of vegetation is increased. A well constructed ditch may have a side-slope varying from $\frac{1}{2}:1$ (one-half foot horizontal to one foot vertical) in stiff clay to $3:1$ in sandy soil.

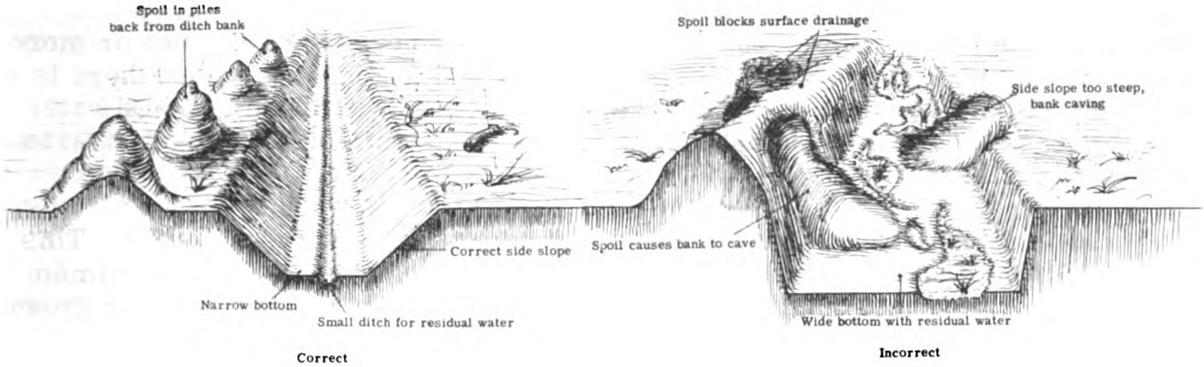


FIG. 76. Cross section of ditches.

If the grade of a ditch is too great, the force of water will undercut the sides and scour the bottom. If the bottom is too uneven, residual pools will remain after flow has stopped and in these pools aquatic vegetation will flourish and mosquitoes will develop. If the ditch is too flat, silt will settle out and pond the water behind it. In malaria control ditches, a grade of about 0.2 per cent (0.2 foot drop in 100 feet of ditch) is usually best. Grades in excess of 0.6 per cent or less than 0.05 per cent are generally unsatisfactory.

In actual practice, the selection of the grade to be used is dependent upon several factors, most important of which are the length of the ditch and the available difference in elevation between the upper and lower ends. For example, if a swamp is to be drained into a stream 1,000 feet distant and the difference in elevation between the swamp and stream is one foot, the maximum grade that can be obtained will be 0.1 per cent. A level of some kind should generally be used to determine the grade. The human eye is a poor surveying instrument and is not reliable for estimating relatively small differences in elevation. The character of the soil in regard to scouring and the volume of water to be disposed of should also be considered. When possible, a uniform grade should be used throughout, since changes in grade increase erosion and silt deposition.

The excavated dirt (spoil) should be disposed of according to a definite plan and never in such a manner as to block natural drainage. When not needed for filling, it should be placed in piles, with drainways in between, rather than in a continuous embankment; and it should be thrown back far enough (at least two feet) so that its weight will not cave in the side of the ditch.

To drain an area by means of ditches, it is common practice to lay out a system composed of one or more main (primary) ditches to conduct the water from the breeding area to a suitable outfall such as a bay or natural water course. Each main ditch may have one or several lateral (secondary) ditches to collect water that does not readily drain into the main ditch. To reduce maintenance the number of outfalls should be kept at a reasonable minimum. Where practical, two or more main ditches may be brought to the same outfall. Occasionally, where there is no suitable outfall near the area to be drained, ditches may be used to bring water to the lowest point in the adjacent terrain, where it can be more effectively treated by oiling or dusting.

Main ditches should be laid out in a straight line whenever feasible. This minimizes erosion and also provides the shortest possible ditch with maximum utilization of available grade, an important consideration in relatively flat ground. Where intervening high ground or other topographic features make a straight ditch impractical, it is best to locate main ditches along the courses of natural drainage. Changes in direction should be few and in the form of curves rather than abrupt angles.

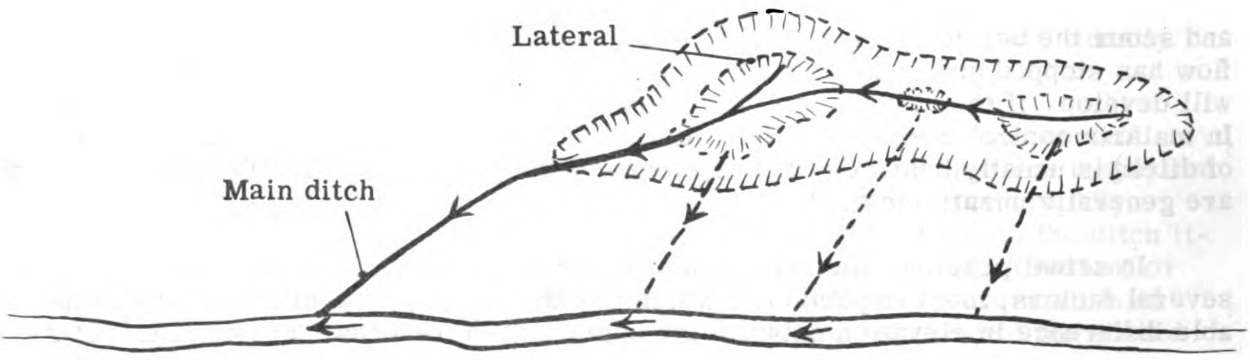


FIG. 77. Ditch systems. Solid line correct. Dotted line incorrect--too many outfalls.

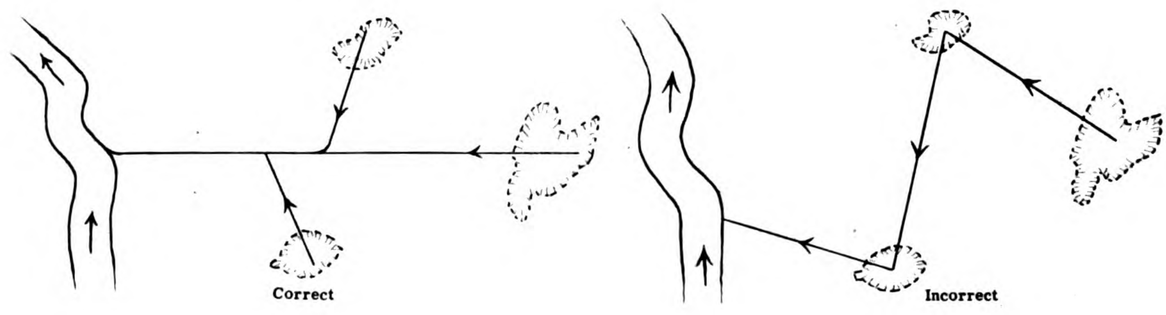


FIG. 78. Ditch alignment.

The usual procedure in laying out a drainage system is as follows:

1. Determine the general locations of all the main ditches by an inspection of the area. When no suitable maps are available, a working map should be prepared before any extensive drainage is undertaken. (See discussion of Surveying and Mapping).

2. Make a preliminary survey of the proposed ditch lines to determine the comparative elevations of outfalls, the area to be drained, and any intermediate high or low points. Frequently, the terrain is such that the best locations for the main ditches are evident without a preliminary survey.

3. Determine the final locations of the main ditches on the basis of the preliminary survey. Then set up stakes to mark the center line and make a profile survey from which a profile of the ground surface may be plotted. The depth and grade of the ditch are determined from the profile. Depth should be kept within the practical limits of the means of excavation (hand labor or machine). Where available fall approaches zero, suitable drainage can sometimes still be effected by depending upon displacement to move the water along the ditch. Displacement ditches are frequently used in salt marsh drainage, where tidal fluctuation and surface-feeding fishes inhibit mosquito breeding.

Ditches are sometimes dug around the outer edges of swamps, usually at the foot of the slope from the high ground, to intercept subsurface seepage water. To determine the depth to which the ditch must be dug to intercept the subsurface flow, several test holes should be sunk to the water table around the perimeter of the swamp.

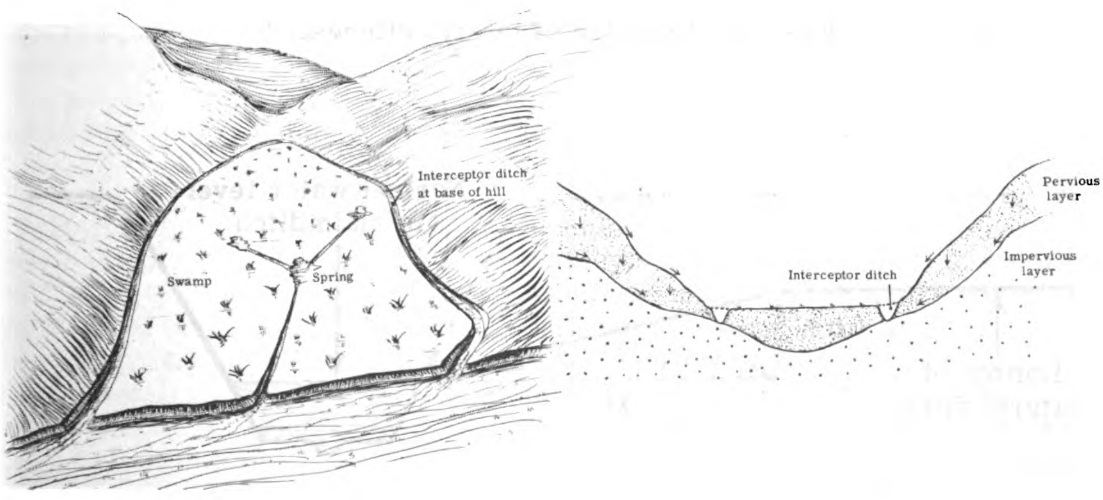


FIG. 79. Interceptor ditches. Perspective, cross section.

Laterals are laid out in the same manner as main ditches. The number of laterals should be kept to a reasonable minimum at the outset, for small breeding spots close to the ditch system may later dry out by percolation of the water into the ditches.

Ditches should be brought together at an angle of about thirty degrees with the direction of flow. The ridge formed at the apex of a lesser angle is likely to cave in. Where the angle is very much larger, the smaller ditch may be blocked by silt deposited by back water from the larger ditch, and a strong flow of water in the smaller one may erode the opposite bank of the larger. Three-way ditch connections should be avoided because of the excess bottom width at such unions. It is desirable to have laterals enter above the normal level of the main ditch. This will prevent water in the larger ditch from backing into the lateral and depositing silt or forming a quiet pool in which larvae will breed. A difference of a few inches or a foot should be sufficient. The fall into the main ditch should not be vertical but distributed over a distance of perhaps ten feet on the lower end of the lateral.

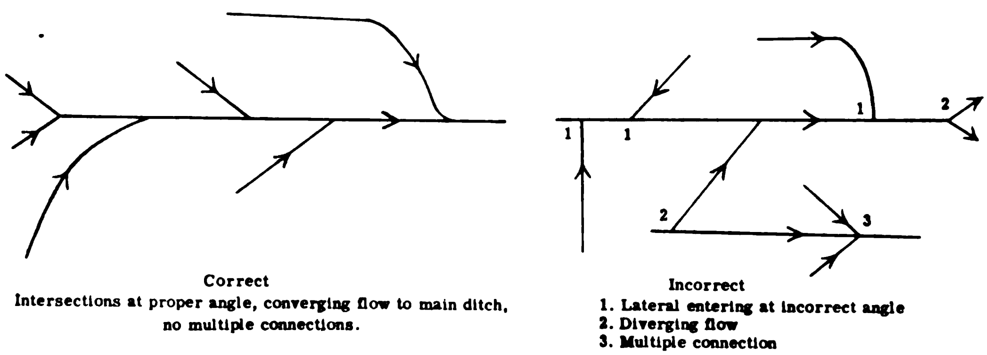


FIG. 80. Location of lateral ditches.

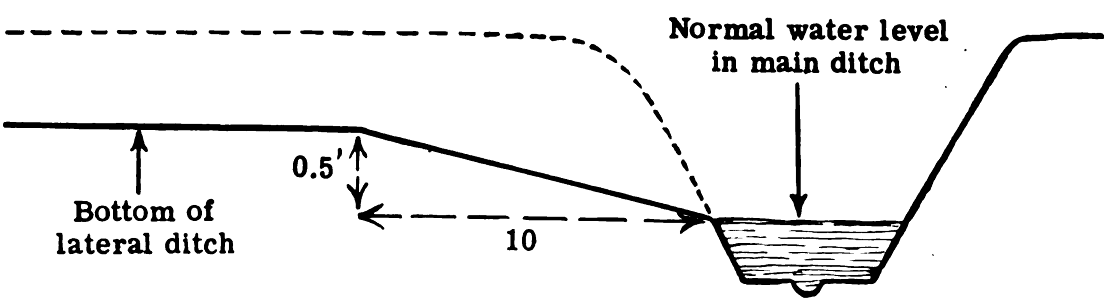


FIG. 81. Lateral entering main ditch above normal water level.

As the first step in ditch construction, any trees or other obstacles that will interfere with excavation or disposition of the spoil should be removed. Cut brush and timber should be removed from the ditch right-of-way and placed where it will not block surface drainage. Excavation may be done by hand labor, machinery, or blasting. Each has it advantages and limitations.

Ditching by hand labor is the slowest but most accurate means and may be preferred to other methods when the ditch is not large, when labor is plentiful and cheap, and when time is not a limiting factor. Hand labor may also be used to dress off or finish a machine or blasted ditch, particularly if later permanent lining is to be installed. Hand dug ditches less than six inches deep are likely to wash and fill rapidly. On the other hand, ditches exceeding three feet in depth may usually be dug more rapidly and cheaply by other methods.

Excavation by machinery is much more rapid than by hand labor, but is not so accurate in grade and cross section. Where small amounts of sheet water are to be removed and the ground is wet but sufficiently firm to support a vehicle, a truck may be used to make ruts to serve as temporary shallow channels. This procedure must be used with caution, for in some localities water held in vehicle ruts will support anopheline breeding. Plows and V-crowders are also used for temporary ditches.

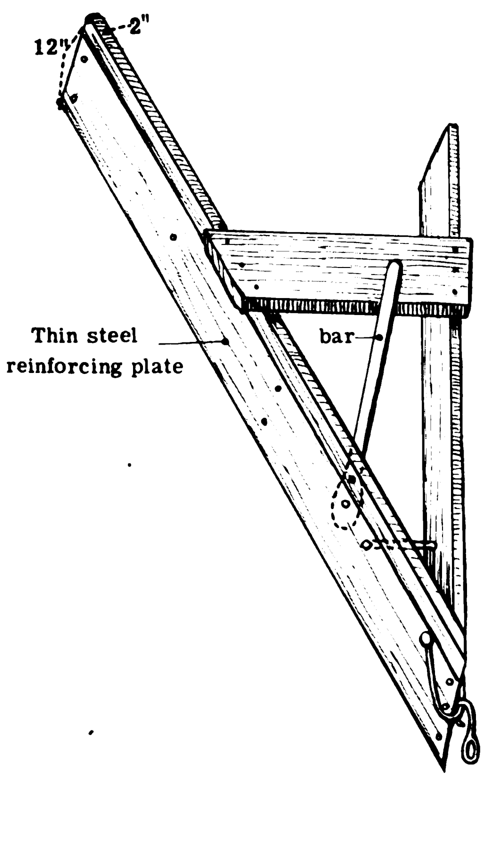


FIG. 82. Wooden V-crowder.

The dragline is the most serviceable machine for digging large ditches. It can be used on either dry or soft ground. In the latter case, plank mats must be used to keep the machine from sinking. A good operator will dig 200 to 1,000 feet of ditch per day, depending upon the size of ditch and soil conditions. A dragline cannot be used efficiently where the depth of ditch is less than two feet.

A ditch-digging machine having buckets mounted on an endless chain is sometimes employed in drainage work. Most of these machines make a ditch with vertical sides, so that the side slope must be put in by hand. The spoil is thrown out in a continuous bank which must be broken at frequent intervals to allow drainage into the ditch. This type of machine cannot be used on mats and, therefore, is not useful on soft ground. The new models will dig up to ten feet of ditch per minute.

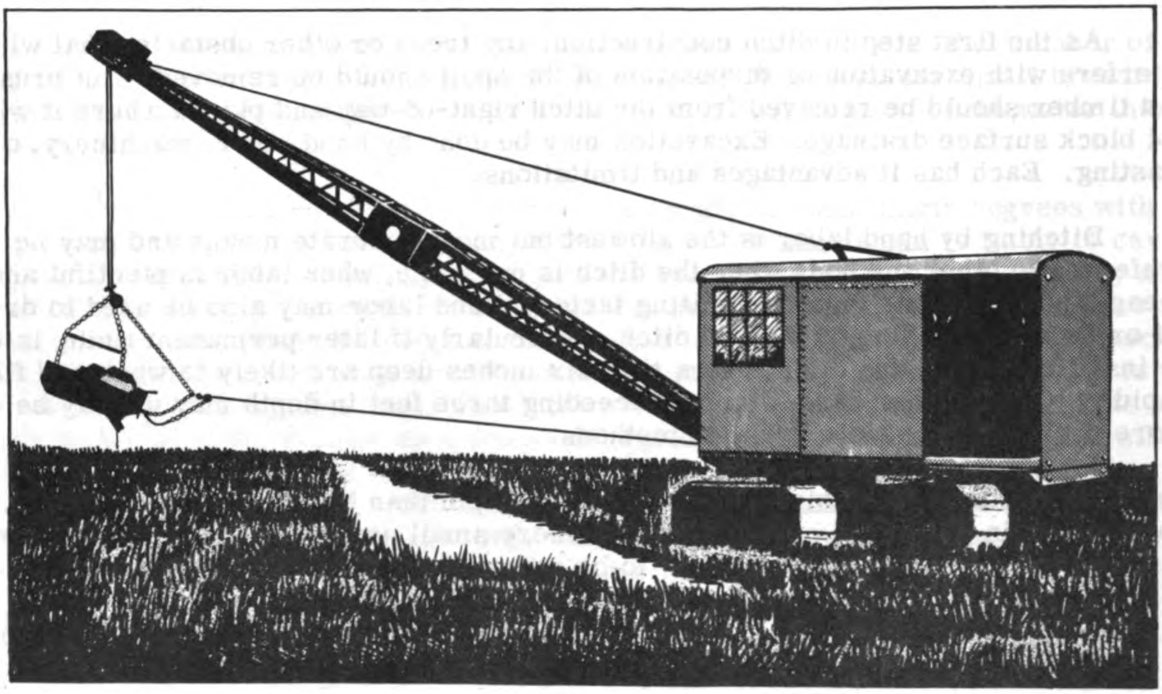


FIG. 83. Dragline in operation.

Blasting is frequently the most satisfactory method of making malaria control ditches. It has the following advantages: a large quantity of earth is moved in a short time with a small amount of labor; a ditch can be made through land too soft for hand labor or machinery; it leaves no spoil bank; the cost is much less than for hand work; and a dynamite ditch fits into a camouflage scheme better than a hand or machine-dug ditch. The disadvantages are: the grade and the shape of the cross section of a blasted ditch are more irregular than in hand or machine dug ditches, and thus the maintenance problem is likely to be greater; blasting is not satisfactory in dry or sandy soils, nor can it be used to make a small shallow ditch; explosives cannot be used near structures,such as buildings or water lines, that might be injured by falling debris or concussions; and finally dynamite is dangerous and must be handled only by experienced and responsible personnel.

The explosive most commonly used for ditching is 50 per cent straight dynamite. This type is more sensitive than many other commercial explosives and must be protected from undue shock or heat. Because of its higher sensitivity, this type of dynamite, when used in wet soil, can be exploded by propagation; that is, a detonating cap is placed in only one stick, the remaining charges being exploded by concussion. In soils too dry and loose to fire by propagation, each charge must be primed. Gelatin dynamite is sometimes used for ditching, but it will not fire by propagation.

The spacing of charges and the number of sticks used in each hole will vary with the size of ditch desired and the type of soil. The table following gives an

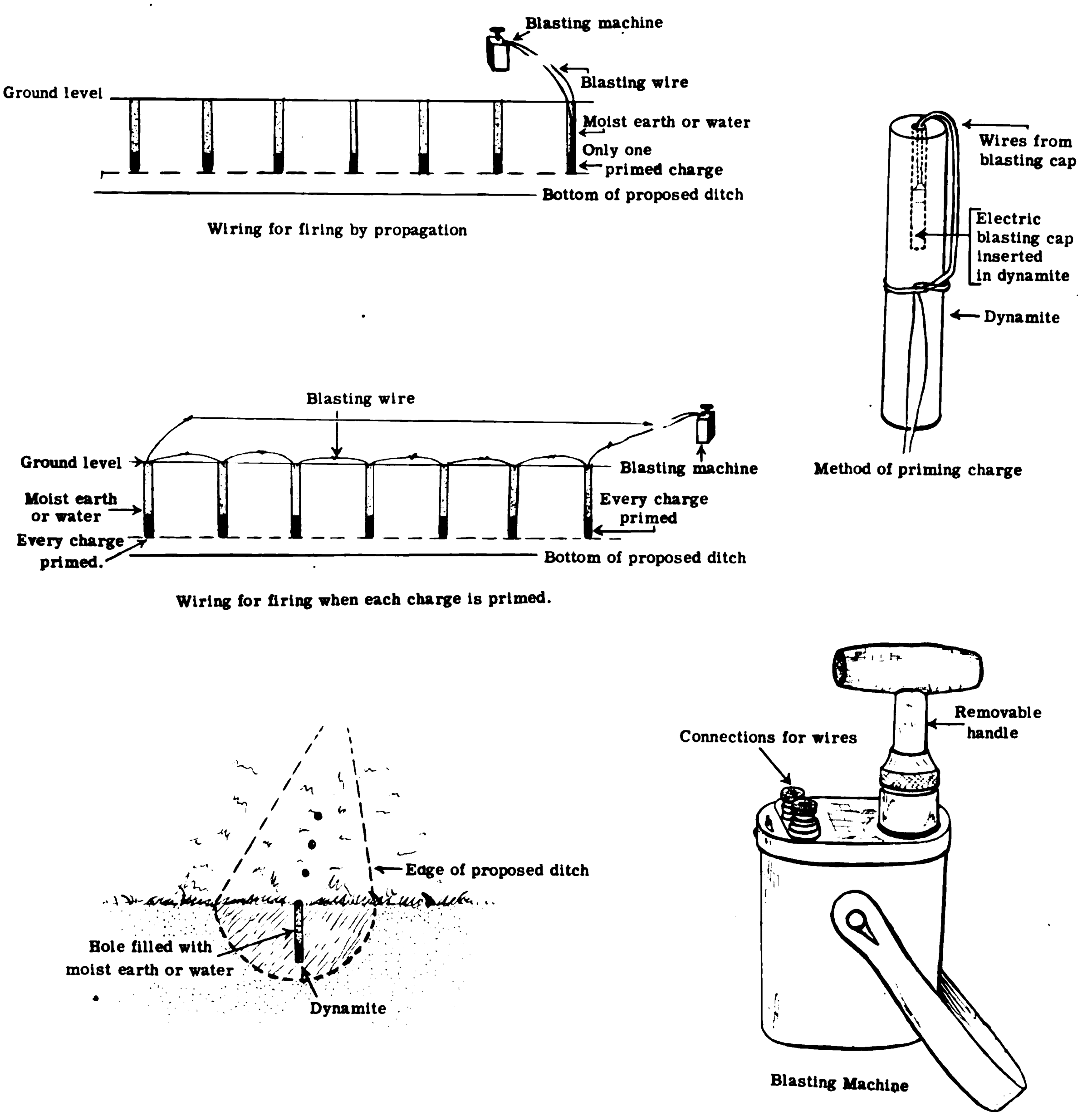


FIG. 84. Dynamite ditching.

approximate spacing. The depth of the ditch can be increased by using heavier charges and placing them deeper. For a depth of five feet or more it is necessary to use two rows of charges. It is always well to make a test shot of fifty feet to determine the most effective spacing.

Dynamite Ditching:

Depth required in feet.	Spacing between holes.	Depth of holes in inches.	Sticks per hole
2	12"	6	½
3	20"	18	1
4	20"	30	1½

Holes are punched in the soil along the center line of the ditch with a wooden or iron bar. The charge is then placed in the hole and covered with moist earth or water. Where earth is used, it should be carefully tamped with a wooden stick to remove air spaces. Stumps are removed by placing additional charges as shown in figure 85, each charge being primed.

To prime a charge of dynamite, a hole is poked in the end with a tapered wooden stick and a blasting cap inserted as shown in figure 84. Electric blasting caps are usually preferred to fuse caps. They are wired for firing as shown in the same figure.

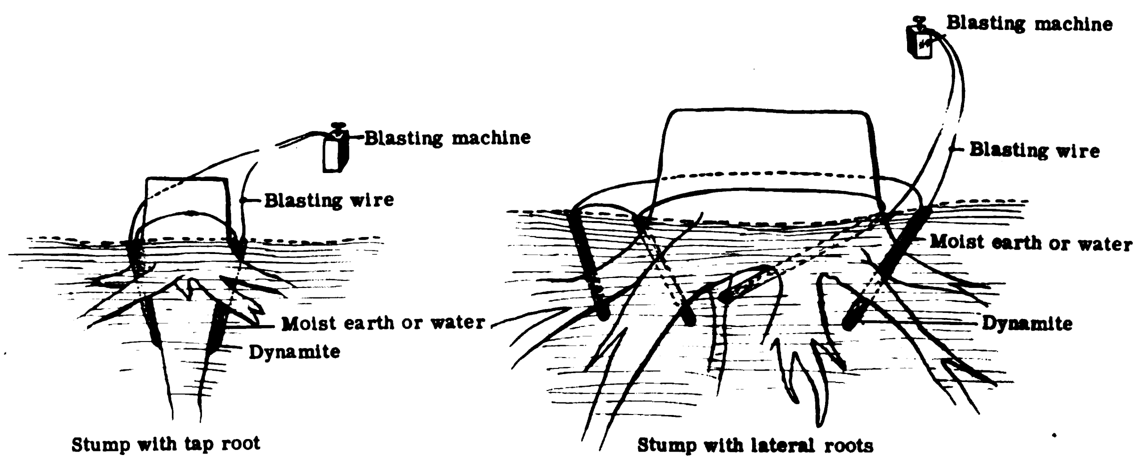
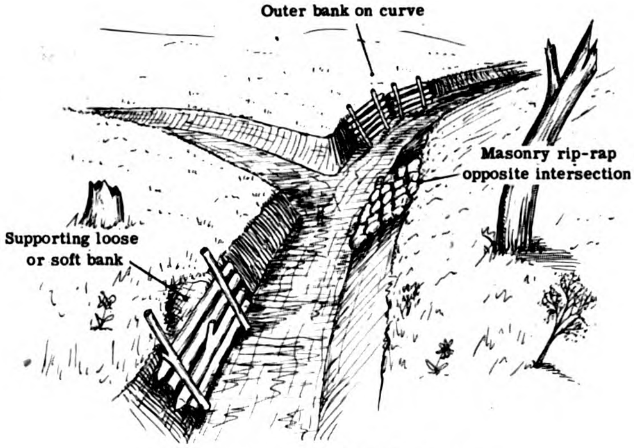


FIG. 85. Blasting stumps.

Explosives are dangerous in the hands of inexperienced persons. Wherever possible, dynamiting should be done only by an experienced blaster. If it is necessary for an inexperienced person to handle dynamite or detonating caps, he must first acquaint himself fully with proper procedures and then adhere to such procedures rigidly.

Various accessory structures, such as rip-rap,linings and culverts, may be built into ditches to reduce maintenance and improve the flow of water. Rip-rap is the term applied to any armor placed along the bank of a ditch to prevent erosion.

It is used to deflect currents around the outer side of a sharp curve or at ditch connections; or to strengthen the side of the ditch where the soil is loose or where an appreciable flow of subsurface water enters the ditch through the bank. Rip-rap may be made of logs piled one on top of the other and staked in place, of masonry blocks concreted together, or of loose angular boulders of sufficient weight to resist movement by the current.



Protection of ditch banks by rip-rap

Anchorage with stakes

Anchorage with pole and wire

FIG. 86. Various types and placement of rip-rap.

<u>Linings</u> are used to prevent both side and bottom (invert) erosion. <u>Invert linings</u>, which serve to protect the bottom of the ditch, may be made of wood, oil drums cut in half longitudinally, masonry blocks cemented together, or concrete. If made of concrete, they may be precast or poured directly into the carefully prepared ditch bottom. Expansion joints are necessary for masonry or poured concrete invert linings. "Weep holes" should be provided in any type at points where seepage water enters. Each section of invert lining should be anchored to the ground by a

footing. A carpeting of short grass makes an excellent lining for the portion of the ditch above the water line. It has the advantage of being better anchored to the bank than rip-rap. Bermuda or similar grass is excellent. It may be established by sodding or by rooting scattered plants. Water and fertilizer may be necessary. Full concrete linings are installed only in permanent systems and their construction should be supervised by an engineer.

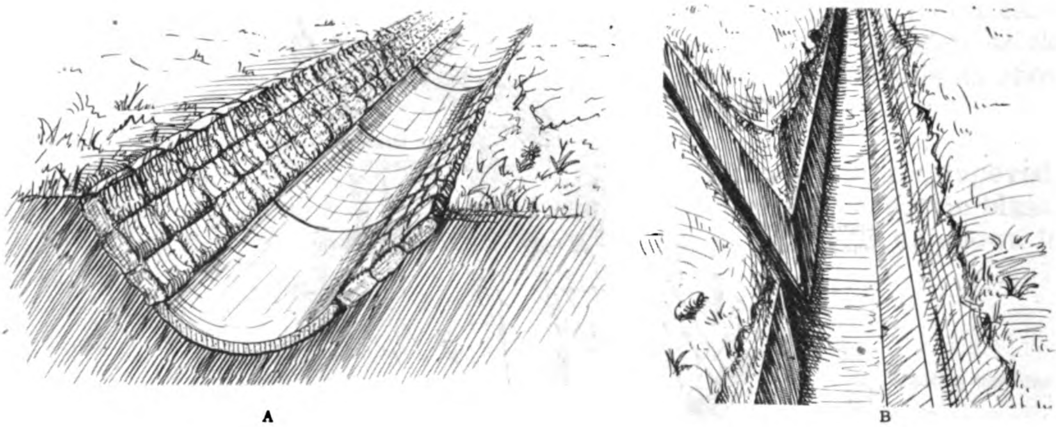
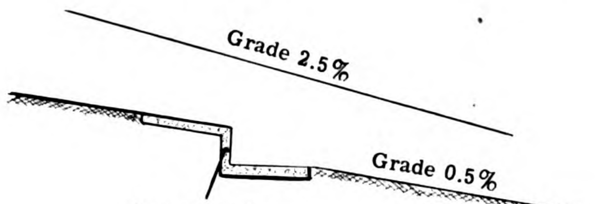


FIG. 87. Ditch linings. A. Concrete invert lining and grass sodding. B. Full concrete lining.

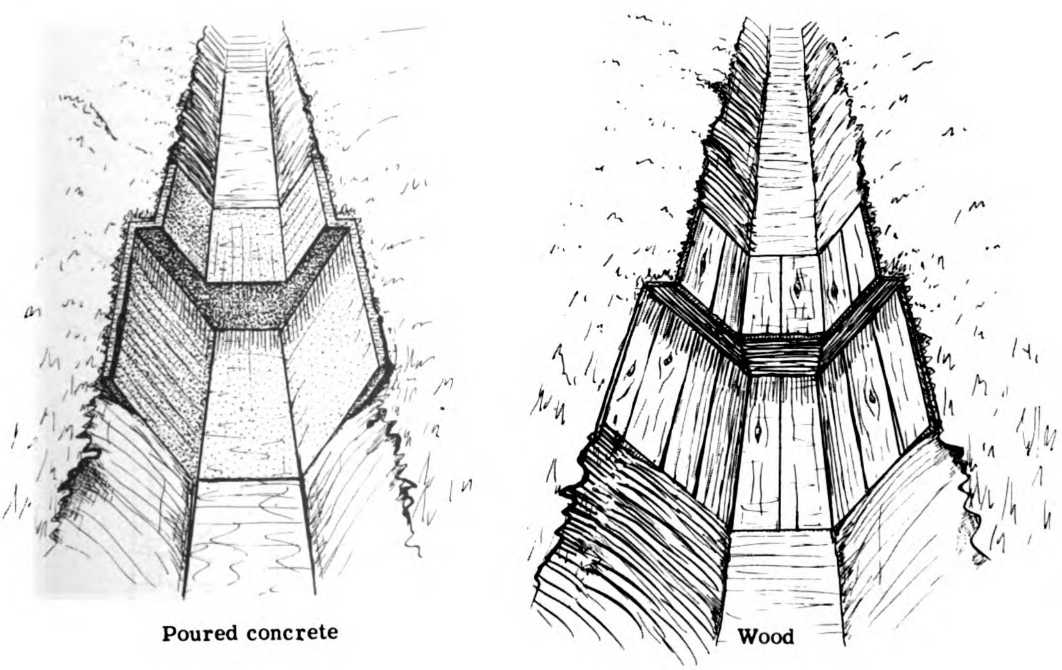
Where the water carries a large amount of suspended soil, sand traps or silt basins are a great aid in keeping ditches and sub-surface drains clear. They should have sufficient volume to retain the water long enough for the silt to settle out and to allow sufficient working room for cleaning.

FIG. 88. Sand trap.

__Steps__ or __drops__ are used to reduce grade where it is impractical to do so by increasing the depth of ditch. Steps may be made of wood, but concrete or masonry is better. Whenever steps are used, they must be properly constructed; otherwise, erosion and silting may render the ditch valueless. The step must have a secure footing in the bottom and sides of the ditch. Aprons must be provided both above and below the step. The lower one should have a zero grade and there should be weep holes to relieve any seepage pressure from above.



Profile of ditch showing use of steps to reduce grade



Poured concrete

Wood

FIG. 89. Steps.

Pipe and box culverts are used to conduct water under roads or through sandy beach barriers or other embankments. They are made of wood, concrete, or corrugated iron. The latter is preferable, since it will better withstand settling and other stresses. Culvert pipes can be improvised by cutting the heads out of oil drums. These work satisfactorily provided the weight of fill and traffic is not great enough to crush them. It is important to place culverts properly to prevent the formation of residual pools of water that may become mosquito-breeders. They should always be placed on the line and grade of the stream or ditch. The size of the culvert should be adequate to carry high water volumes. When a large size is not available, two or more of a smaller size may be used, side by side. Proper footing should be provided to prevent settling, particularly where the culverts are covered by a heavy fill. When necessary, wing-walls or rip-rap may be built around the ends of the culvert to prevent washing around the outside.

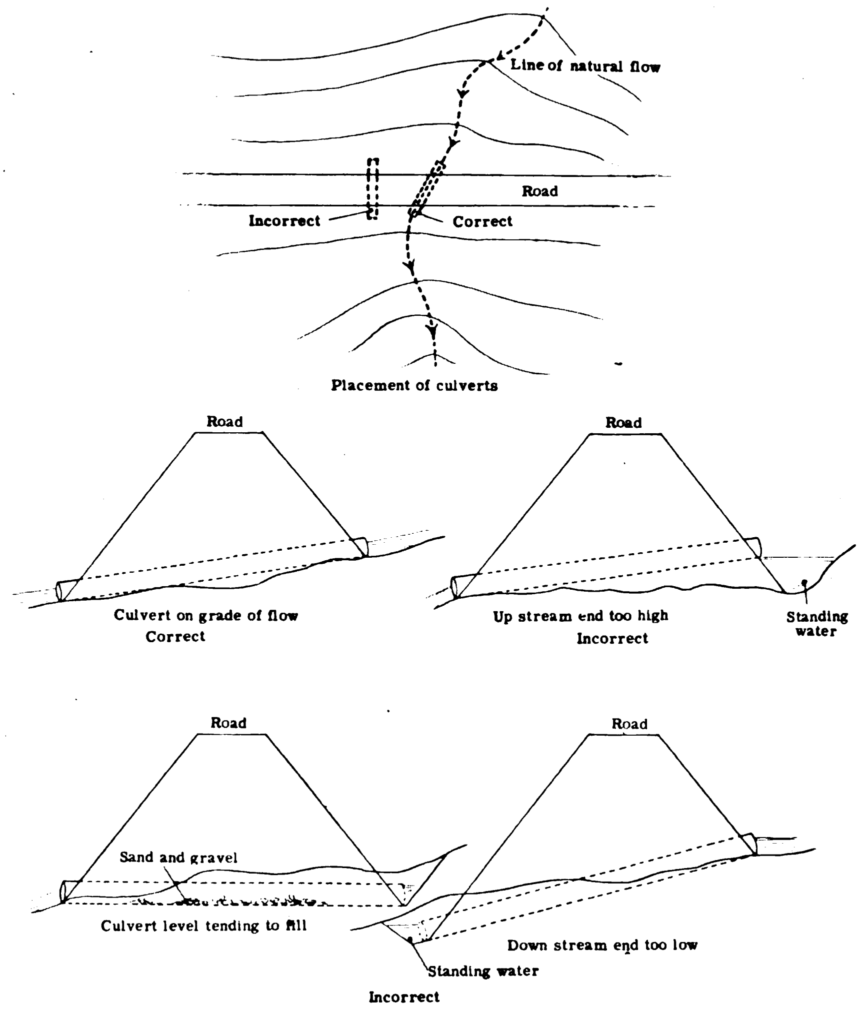


FIG. 90. Correct and incorrect installation of culverts.

Tide gates can be used to prevent tide water from backing into natural water courses or ditches. The gate is hung on a culvert or head-wall and operates like a simple check valve. When the water on the upstream side is low, the pressure of rising tide on the seaward side closes the gate; at low tide, the water pressure on the upstream side opens the gate. Tide gates should be placed low enough to permit maximum drainage but high enough to prevent their being blocked by sand deposits from the sea. The gate itself is usually made of two-inch plank and preferably of

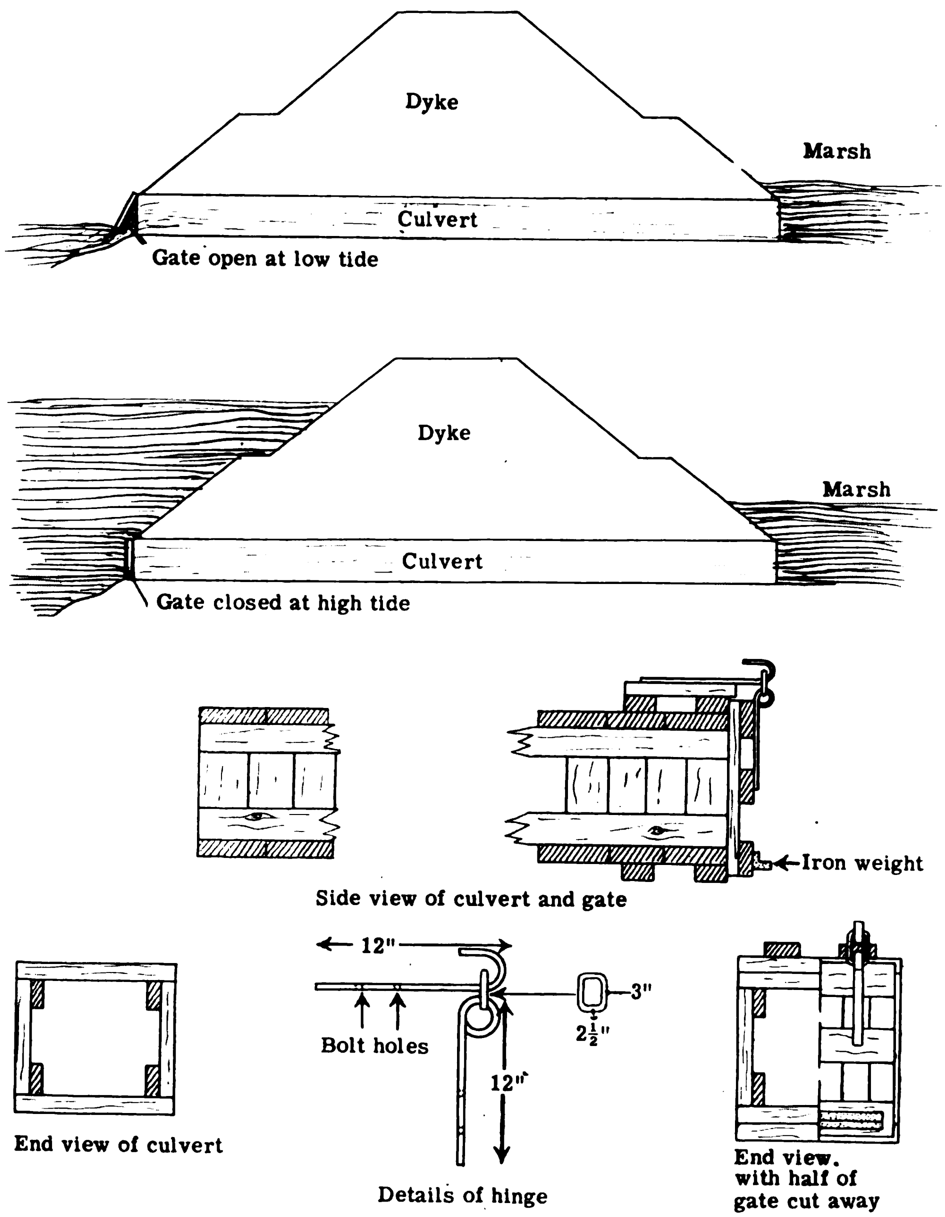


FIG. 91. Placement and construction of tide gate.

clear well-seasoned stock. Size should not exceed 36 x 36 inches. Where a larger discharge orifice is required, use two or more gates side by side. The hinges should be so constructed as to tolerate a certain amount of springing without injury. Otherwise, if flotage or other debris should be caught between the gate and the seat, the hinges will be permanently damaged and the gate will no longer close properly. Sluice gates may be used to impound and release water as desired. The gate is hung in guides set in a head-wall or culvert and is raised and lowered manually.

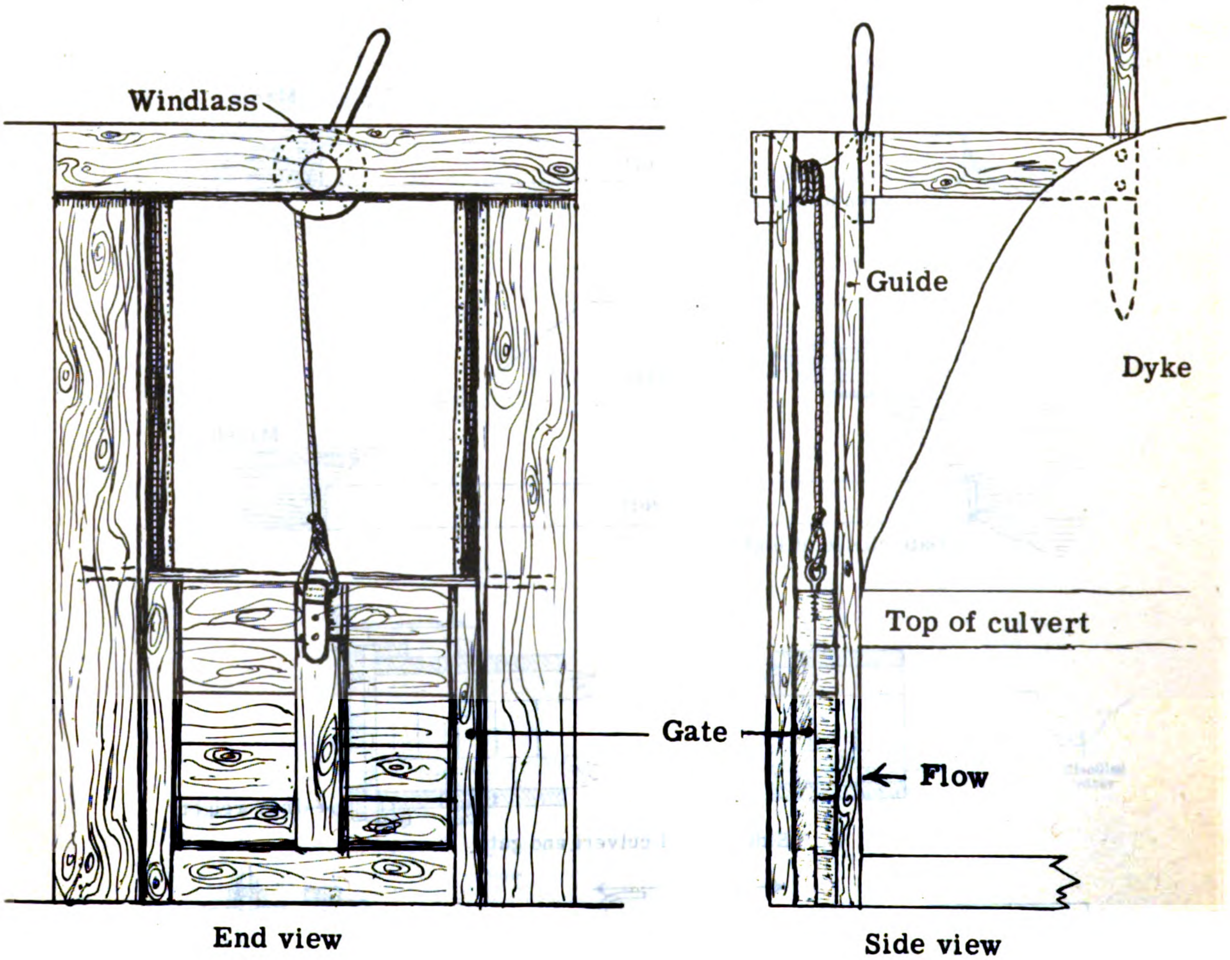


FIG. 92. Sluice gate.

Outfalls discharging into the sea often become blocked by sand washed in by the surf. Breakwaters and arrowheads may be installed to retard the formation of such beach barriers.

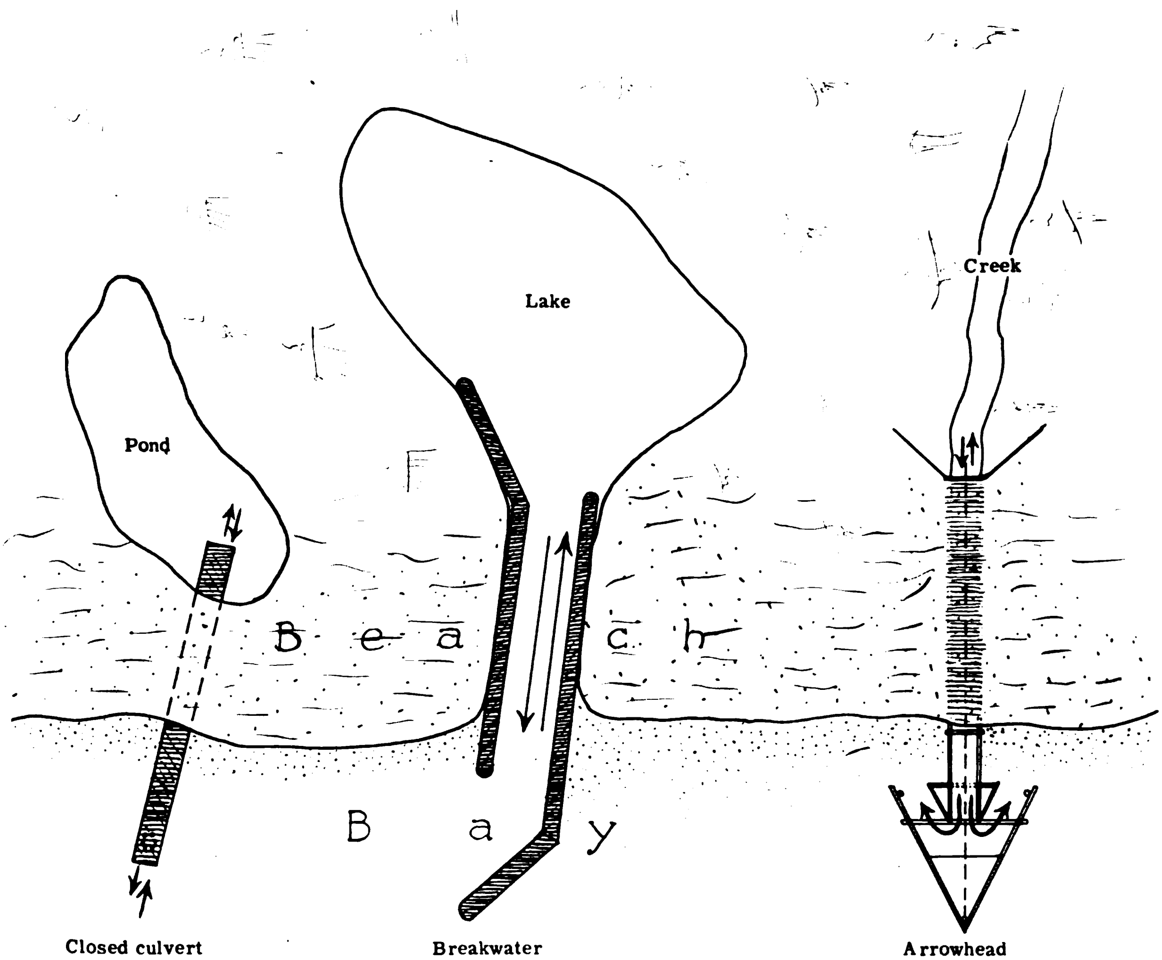


FIG. 93. Structures to retard formation of beach barriers.

Sub-surface drains are used where it is necessary for the ground surface to remain unbroken by ditches; where the earth is so unstable that open ditches cannot be maintained; or when it is advantageous to drain water vertically through an impervious to a pervious stratum. They are considerably more expensive than open ditches and are, therefore, of limited application in malaria control work. Tile makes the most satisfactory horizontal sub-surface drain. Unflared concrete or vitreous pipe may be laid in the bottom of a narrow ditch with the ends butted together. The joints are left unsealed so that water can enter the line, but a strip of roofing paper or similar material is placed over the upper two-thirds of each joint to reduce silting-in. The ditch is then back-filled with rock and earth.

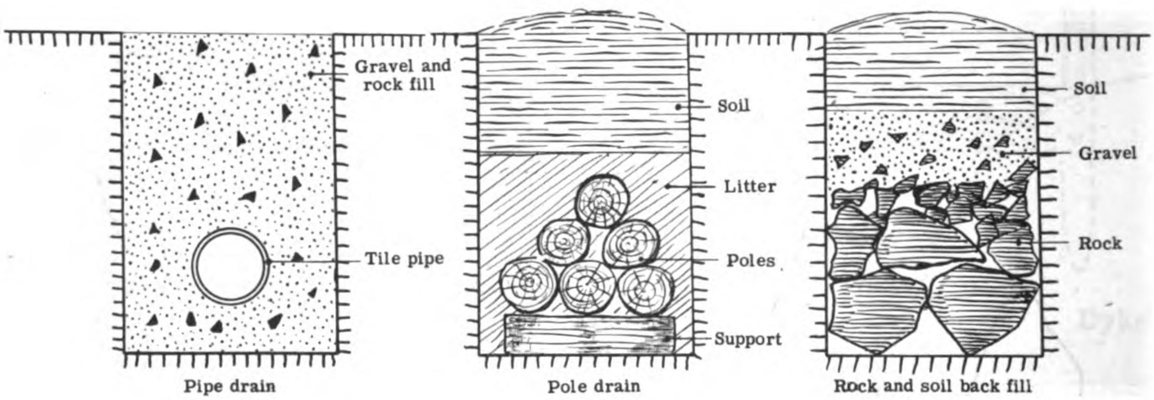


FIG. 94. Sub-surface drains.

If pipe is not available, large rocks or poles may be substituted. These are less satisfactory than pipe because soil eventually fills in the interstices and reduces flow. In short intercepting tile drains carrying only seepage water, the grade may be zero; but where flood waters are to flow through the drain, a minimum grade of 0.3 per cent should be maintained to prevent silting. Grade in excess of 3.0 per cent may cause scouring.

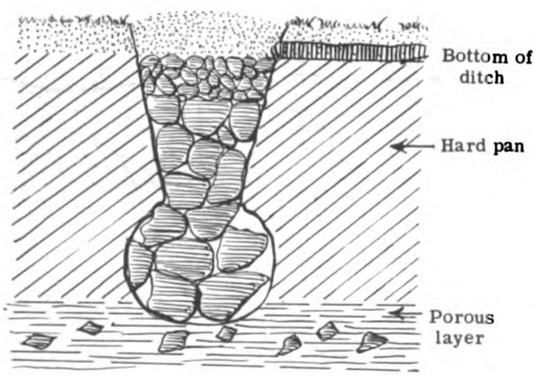


FIG. 95. Vertical rock-filled drain.

Vertical drains are used to carry water through hardpan or other impervious strata into a porous stratum. They may be dug by hand or blasted and, in permanent installations, may be lined with masonry or concrete, if weep holes are provided. To maintain their efficiency, the drains should be cleared of silt deposits frequently.

Natural water courses may sometimes be so **improved** as to rid them of anopheline breeding. Removing obstructions, such as vegetation, fallen timber and sandbars, and smoothing and correcting the side slope will increase the water velocity and reduce the breeding area. Wandering streams may be improved by digging or blasting a new and a straighter channel. The excavated earth from the new channel may be used to fill at least a part of each meander section. Filling should progress from the upper to the lower end of the sections in order to prevent the formation of blocked holes.

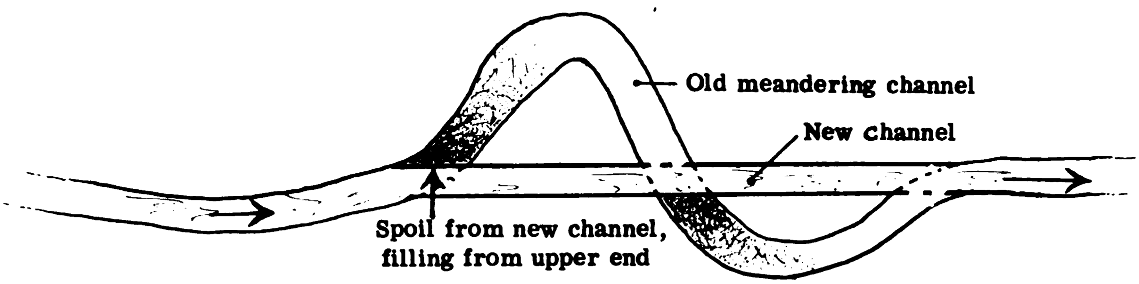


FIG. 96. Channeling.

Filling, when properly done, is the most nearly permanent means of getting rid of standing water, for a good fill requires no maintenance. The practicability of filling, in any particular case, depends on the size of the breeding place, the quantity of fill on hand, and the availability of equipment. Dry fill may be hauled from adjacent high ground, or hydraulic fill may be dredged from a river or bay and pumped to the place needed. Certain precautions should be exercised in making fills. Never place the fill so that it will block the runoff of surface water or springs. Always fill a swamp from the upper to the lower end from the sides toward the center. Where it is necessary, provide a channel for water entering from higher ground. Put in enough earth to allow for settling. In taking earth for dry fill, do not make a **borrow pit** that will hold water and become a breeding place in itself. All borrow pits, whether for malaria control or other purposes, should be self-draining. In using hydraulic fill, move the discharge pipe frequently to get an even distribution of coarse and fine material. This will minimize cracking as the fill dries. Cracks may hold enough water to breed mosquitoes and should be filled by harrowing or dragging.

Some shallow swamps and temporary breeding areas can be most easily dried by **pumping** the water into a stream or onto porous dry ground. This is a temporary procédure and must be repeated whenever sufficient water accumulates to permit breeding. Pumping may also be necessary on drainage projects when the level of the drained area is below the low-water level of the adjacent stream. Such situations require the installation of a **sump** (pool in which to install a pump) and a continuous or automatically operating pump of adequate capacity. Such an installation would ordinarily be justified only in a permanent control project.

MECHANICAL CONTROL OF THE AQUATIC STAGES

The elimination of artificial containers such as tin cans, cracked gourds, boats, and automobile tires in storage will reduce the breeding of some anophelines. Discarded small containers should be collected and buried for reasons of general sanitation, as well as for malaria control. Other containers should be made self-draining, if possible; otherwise, they should be inspected and oiled regularly. Tires in storage can be treated by dusting the inside with Paris green.

In certain localities, important malaria vectors may breed in water-holding plants. These may sometimes grow in such unusual places as to be overlooked. A case in point is that of *Anopheles bellator* in Trinidad, which breeds in water held in certain bromeliads, mainly of the genus *Gravisia*. These plants are epiphytes which grow on the trunks and branches of trees. Control of the vector mosquito consists in cutting the epiphytes off of the trees.

NOTES

ELIMINATING THE MOSQUITO VECTOR

NATURALISTIC CONTROL OF THE AQUATIC STAGES

Naturalistic control is the deliberate manipulation of natural environmental factors for the purpose of bringing about a reduction in the number of mosquitoes in an area. Killing larvae with oil is artificial (chemical) control; reducing mosquito production by intensifying a natural limiting force, such as shade over a pool, is naturalistic control.

When naturalistic control is used, care should be taken that the modifications of shade, salinity, or water levels do not in themselves create conditions favorable to other potential vectors in the area. Several mistakes of this sort have been made in the past. It is obvious, therefore, that the successful employment of naturalistic methods of control is dependent upon an intimate knowledge of the habits and preferences of all species of anophelines in the area. Naturalistic control, on a large scale at least, should, therefore, not be attempted until adequate information on local mosquito habits is available. Too great reliance should not be placed upon this system, and its operation should be checked regularly.

MANAGEMENT OF WATER.

Water level fluctuation in reservoirs does at least three things: strands aquatic stages at the margins; dislodges larvae from vegetation and flotage so that they are more exposed to wave action and fish; and discourages plant growth and strands flotage in the fluctuation zone. Variation of pool level is usually managed to produce a gradual drawdown during the entire breeding season (seasonal recession), or a regular fluctuation between constant limits (cyclical fluctuation), or any combination of these two. The interval of change must be less than the length of life of the larvae and is usually from seven to ten days. In the case of cyclical fluctuation there is usually a drawdown of about one foot followed by a refilling to the original level.

Irrigation systems often are troublesome, mainly because of poor construction and improper management. The irrigation of rice fields presents a special problem. Apparently, the best control system for them is periodic drying; one common practice involves nine days of flooding and two days of drying.

Flushing is employed in rather small streams and channels where there is a continuous and plentiful supply of water flowing slowly enough to permit breeding. Mechanical devices, gates and siphons, are constructed to provide for the periodic damming and discharging of water. This is done in order to discharge large enough volumes of water at least once a week to wash the larvae, pupae, and eggs downstream or to strand them high on the banks. Muddying of the stream by the rush of water probably has a further deterrent effect on breeding. Sluice gates may be either hand or machine operated, and siphons should be automatic. The MacDonald type siphon, shown in the following illustration, is perhaps one of the best.

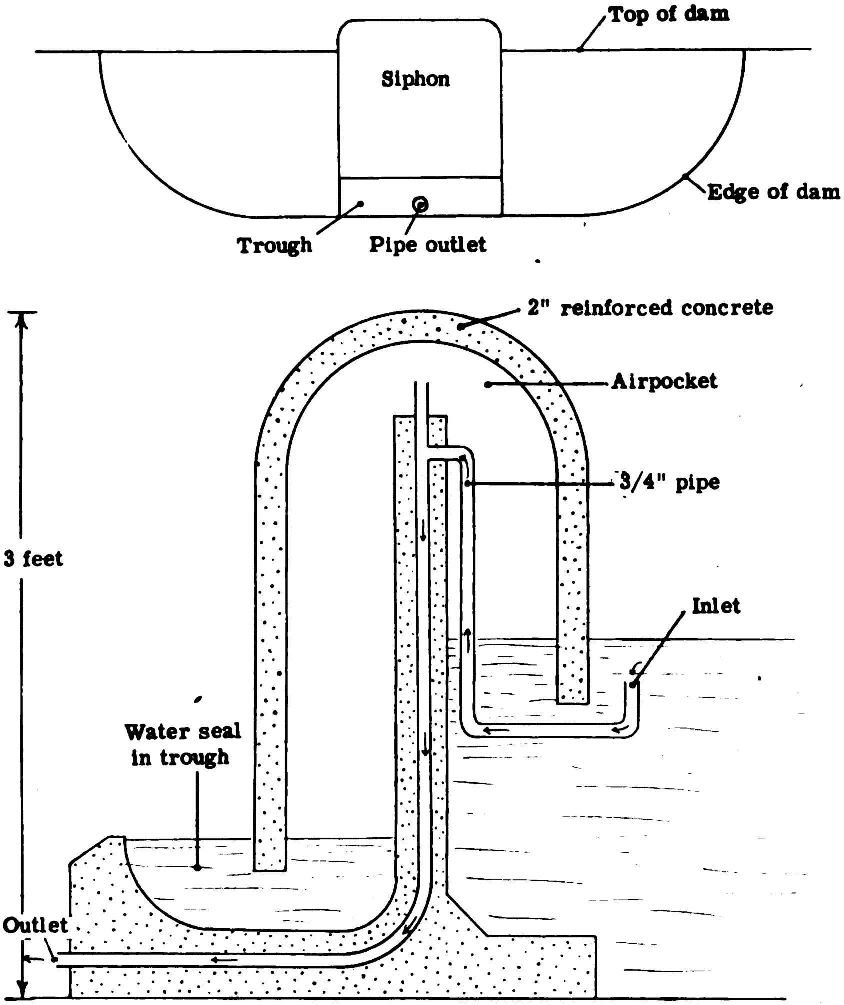


FIG. 97. Mac Donald siphon.

CHANGING THE SALT CONTENT OF WATER.

By increasing or decreasing the salinity of the water in a breeding area conditions may sometimes be altered beyond the limits of tolerance of a particular mosquito species. Some species, however, exhibit a far wider salt tolerance than others. Anopheles punctulatus moluccensis in the South Pacific Area, for instance, will breed in fresh water or in almost pure sea water and is, therefore, a species that does not lend itself to control by alteration of the salt-content of its breeding waters.

Salt water in tidal flats may be freshened by installing tide gates to keep the sea water out while the natural fresh-water drainage gradually dilutes and washes out the residual brackish water. The water in fresh-water flats may be increased in salinity by providing simple ditches for tidal movement onto the flat, or salt water may be held on the flat by the use of reverse tide gates.

NATURALISTIC CONTROL OF THE AQUATIC STAGES

REGULATION OF SUNLIGHT AND SHADE.

Some anopheline species breed only in bright sunshine and may be greatly reduced in numbers by a maximum shading of breeding areas. The simplest procedure in some cases is to allow natural rank growth to accumulate, or certain particularly desirable shrubs may be planted. Structures of cloth, fiber, or wood may also be erected over wells, around the edges of ponds, and along stream margins. The effects of shading may be indirect, the reduction in breeding resulting from the decreased plant growth and increased predation by fish rather than from the direct effect of the shade on the mosquitoes themselves.

Against those species that prefer a dense shade or a mixed condition of sunshine and shade, clearing to let in sunshine may be an effective aid in control. Clearing may be limited to overhead vegetation or to low-lying growth on the water's edge, or both types of vegetation may be removed. Clearing not only admits more sunlight to an area, but promotes evaporation from sun and wind action, thus drying many shallow pools.

INTRODUCTION OF NATURAL ENEMIES.

Of all the natural enemies of mosquitoes, only certain of the surface-feeding fishes have been definitely established as being of practical value in malaria control. The killifishes (Fundulus) in salt water and the top minnows (Gambusia, Lebistes, Panchax) in fresh water are the most useful. Gambusia affinis is the most important species. It can be introduced successfully into any tropical or temperate climate where severe freezing winters do not occur. This species is adaptable to anopheline larval control because it possesses the following biological characteristics: it has a normal habitat corresponding closely with that of mosquito larvae; it is alert and searches in emergent and floating vegetation for larvae; it has a high food-preference for larvae in natural surroundings; it reproduces rapidly in nurseries and natural bodies of water; it is very hardy and adapts itself readily to a wide variety of waters - deep or shallow, open or confined, clean or organically polluted, fresh or brackish - in tropical and temperate climates; it withstands handling and transportation well; it is worthless as a food for man, and, therefore, remains unmolested; and it is very rarely destructive to other fishes.

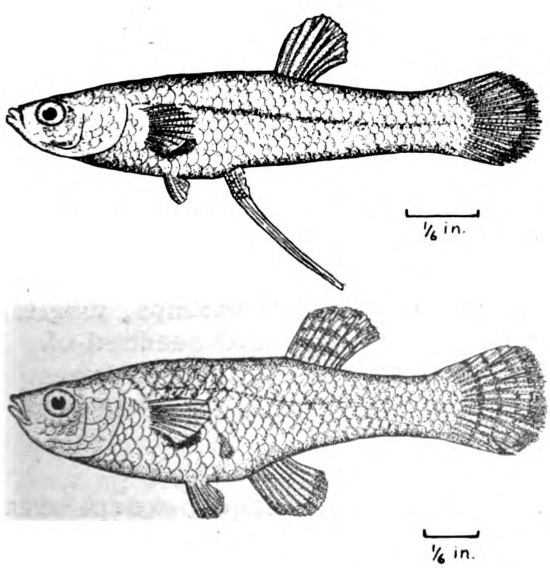


FIG. 98. Gambusia affinis. Upper, male. Lower, female.

NATURALISTIC CONTROL OF THE AQUATIC STAGES

MANAGEMENT OF POLLUTION.

Anophelines in general do not breed abundantly in polluted water. The inhibiting effect of pollution probably results both from direct toxic action and from microbic and physical effects on the larvae and their food supply. Waters may be deliberately polluted with industrial wastes, sewage, or cut herbage and leaves.

CONTROL PROCEDURES

PREVENTING MOSQUITOES FROM BITING MAN

The preceding discussion of Malaria Control has dealt with methods of destroying two of the factors essential to the existence of malaria, the parasite and the mosquito. While it is a purely academic consideration to think of destroying man, the third factor, it is possible and practical to achieve the same purpose by separating him from mosquitoes by natural or artificial barriers. Such measures preclude the passage of the parasite from man to mosquito and from mosquito to man, thus breaking the transmission cycle. The separation of man and mosquito depends for its success in many ways upon the instruction and discipline of troops. Every man should be taught, through lectures, movies, demonstrations, and posters, the seriousness of malaria and the measures he should adopt to avoid the disease. The application of these measures should then be rigidly enforced.

PREVENTING MOSQUITOES FROM INFECTING MAN.

By avoiding malarious areas, uninfected men erect a distance barrier between themselves and infected anophelines. If tactical considerations permit, campsites and shore stations should be located beyond mosquito flight range from known or suspected malarious areas. High open ground is more favorable than low swampy ground, and windward exposures are safer than those in the lee of swamps, jungles, or hills. Since the native population usually constitutes the principal seedbed of malaria infection, it is desirable to locate camps at safe distances from villages. If this is not possible, an effort should be made to have the villages themselves removed from the zone of control.

All military personnel should be restricted from native villages, except when in the performance of official duties. The danger is especially great inside the huts, both day and night, and anywhere in the open village after sundown. Exposure to bites is to be avoided at all times and places, whether well within or far without the limits of the base control zone. Outdoor gatherings at twilight and after dark for movies, games, picnics, swimming, or the use of open showers should be strictly prohibited when anopheline vectors are present.

PREVENTING MOSQUITOES FROM BITING MAN

Bites by mosquitoes present in the occupied area may be prevented through the use of certain devices. Repellents are now available which, if properly applied, keep mosquitoes away from exposed skin surfaces for a short time. Additional applications must be made at intervals depending upon the composition of the repellent, the rate of absorption by the skin, and the amount of perspiration of the individual. With prolonged use, some men may develop a skin reaction from the chemical. Persons should be cautioned about getting repellents in the eyes, for some kinds are very irritating. A number of preparations have been developed recently and supplied for individual use. These are Indalone, Rutgers 612, dimethylphthalate, and isopropylcinnamate. GI repellent is at present a mixture of the first three compounds. Directions for use are given on each container. Some repellents may be very effective against certain species, but fail against others. The effectiveness of a malaria control repellent must, therefore, be judged against the local anopheline vector and not against other pest mosquitoes. It is likely that very much better repellents will soon be developed as a result of intensive work now in progress. Smudges may sometimes be used to good effect to repel mosquitoes and should not be forgotten when repellents are not available.

Protective clothing is a very practical barrier against mosquitoes. In a malarious area, men should not go about half-dressed after sundown. Shirt sleeves should be rolled down and collars buttoned; full length trousers should be worn and the ankles protected either by leggings or by folding the trousers under the socks. Repellents should be applied to areas of the clothing that are pulled tightly against the skin, as across the shoulders and buttocks. Additional protection may be afforded by head nets and gloves.

A bed net is one of the best protective devices the individual can use. Nets should be made of bobbinet or other strong material having twenty or more meshes per inch (apertures not larger than 0.0475 inches). The net should be large enough so that the hands, knees, elbows and other parts of the body will not touch the sides during sleep. A length of flexible bamboo or other similar material may be used to bow the net out at the level of the shoulders and knees. A strip of muslin eighteen inches wide sewed around the bottom of the net will prevent tearing and give additional protection in case any part of the body does come in contact with the net. The use of the muslin strip should not be enforced if it so interferes with ventilation as to jeopardize the consistent employment of the nets. The net should be rolled up in the daytime to prevent mosquitoes from using it for a resting place. At night the net should be hung from supports and the lower edge tucked under the mattress or blanket. The net should always be hung inside the supports; if draped over the supports, it will be impossible to tuck the lower edge under the mattress without leaving small apertures around the bottom through which mosquitoes can enter. Upon retiring, the inside of the net should be carefully examined and any mosquitoes found there killed by hand. Nets should be kept in good repair with adhesive tape or sewed patches.

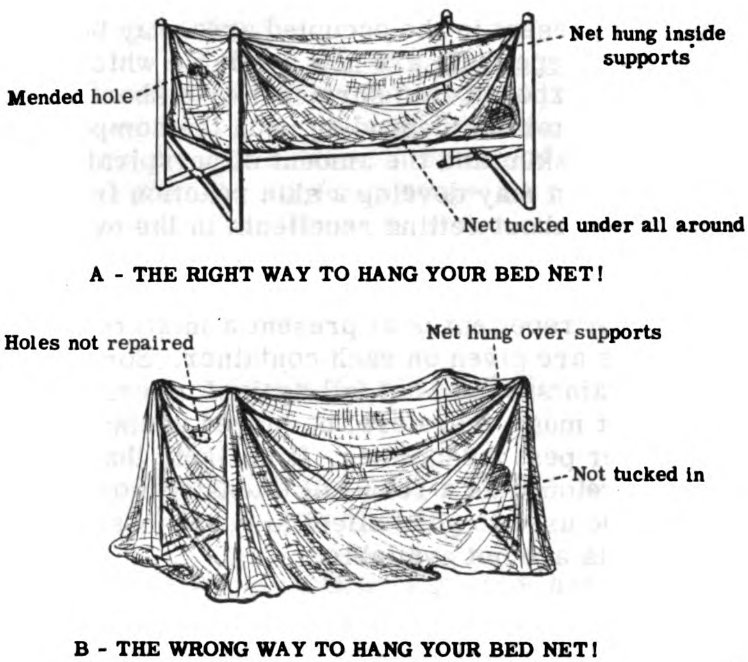


FIG. 99. How to hang a bed net.

Mosquito proofing should be used wherever possible in quarters, recreation halls, heads, and buildings where night watches are maintained. Doors, windows, and ventilators should be screened. Screen should be eighteen-mesh and of metal or plastic rather than cloth. Bronze or copper screening will withstand corrosion much better than iron, but the lasting qualities of iron screen can be increased by frequent painting. A satisfactory plastic screening has recently been made available. It has the advantage of being non-corrosive and holes can be repaired easily merely by fusing a patch into place. However, the mesh is easily spread and the plastic will melt if exposed to flame. Window screen should be made to cover the entire area of each window. They should be solidly secured to the window sash and all cracks caulked. Removable screens, or sectional screens covering only part of the sash, cannot be kept mosquito tight. Casement windows or other types that open outward should either be rehung so that they open inward, or screening should be so constructed as to permit opening of the windows from the inside.

It is desirable that the number of doors in a building be kept to the minimum necessary to handle the traffic. Every doorway offers a possible entrance for mosquitoes and increases the maintenance work. If possible, doors should not be located on the leeward side of buildings or re-entrant angles, because mosquitoes tend to collect in such places. Always hang screen doors to open outward. Two doors with a vestibule between are desirable in highly malarious areas. Screen doors must be rugged to remain serviceable. Good quality clear lumber should be used for the frame; joints should be reinforced with sheet metal triangles; places where a foot or hand may be applied to push open the door should be protected by

wooden cross strips; and hinges should be heavy enough to stand the wear and tear. When suitable hinges are not available, substitutes must be improvised. Leather or pieces of rubber tires will serve. Fairly good hinges can also be made of clear hardwood.

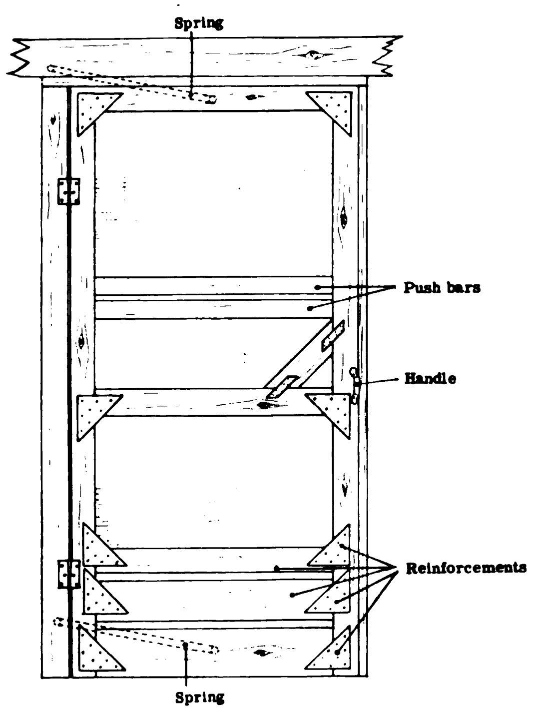


FIG. 100. **Properly constructed screen door.**

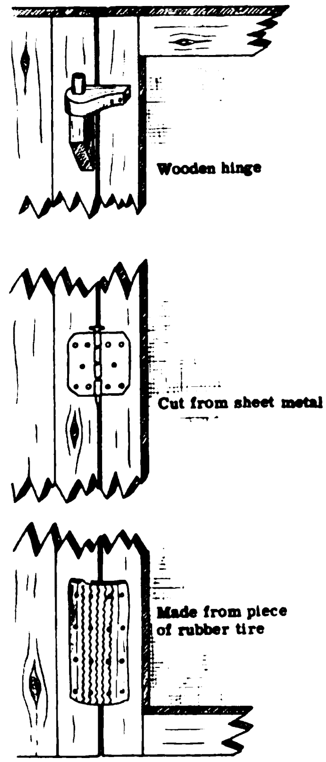


FIG. 101. **Improvised hinges for screen door.**

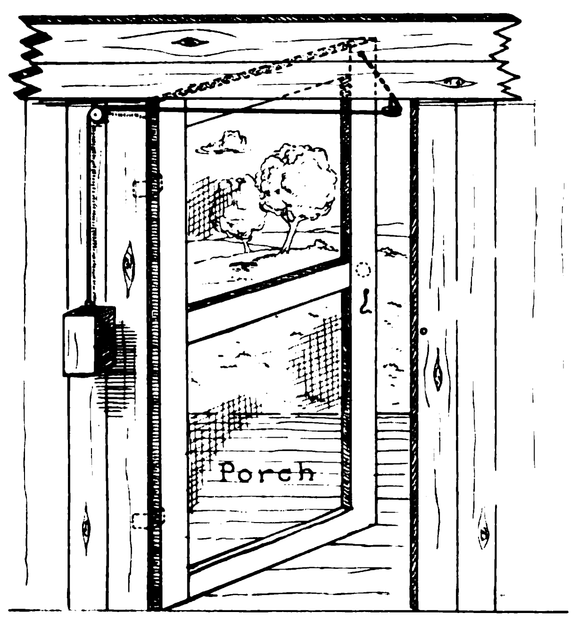
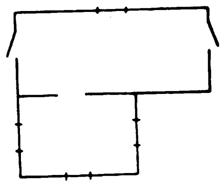
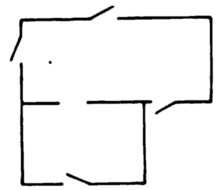


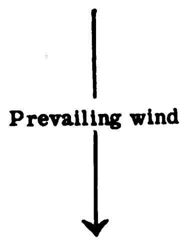
FIG. 102. **Screen door with counterweight in place of springs.**

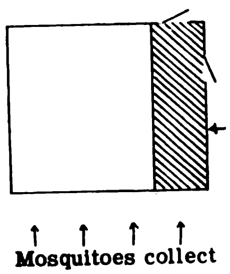


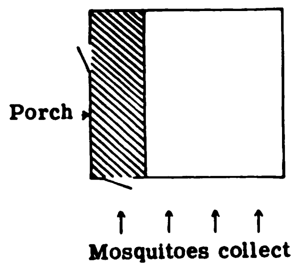
Correct
Cross-ventilation good, windows in place of doors whenever possible, doors open outward.



Incorrect
Cross-ventilation poor, too many doors, too few windows, one door in re-entrant angle, one door opens inward.

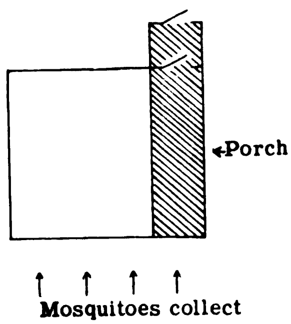






Correct.
Doors placed and hung correctly
Prevailing wind tends to keep doors closed.
No doors on leeward side.

Incorrect.
Doors placed and hung incorrectly.
Prevailing wind tends to keep doors open.
Door located on leeward side.



Correct
In highly infected areas use two door vestibule.

FIG. 103. Placement of windows and doors for ventilation and in relation to prevailing winds.

Human nature cannot be depended upon to keep screen doors closed, so some mechanical device must be utilized. If the conventional type of coil spring is at hand, use two on each door, one at the top and one at the bottom. In the absence of springs, a counterweight on a line will do. Batten strips should be nailed around the edges of the door to close the crack between the door and the casing. Four-way cross-ventilation should be provided if possible in order to encourage the men to remain inside.

All cracks, knotholes, and spaces under the eaves must be closed. Small holes may be covered with flattened pieces of tin cut from cans. Cracks in floors and walls should be caulked. A good caulking material may be made by boiling shredded toilet paper and flour to a homogeneous mass and then adding sand and cement until a workable consistency is reached. Any compressible or mouldable substance, such as oakum, cotton mattress filler, or roofing cement can be substituted. A rigid program of inspection, maintenance and discipline should be instituted. In quarters it is often desirable to have one occupant designated as maintenance orderly. He is then charged with the responsibility of making minor repairs promptly and reporting any needed work for which he does not have equipment. The actual work of mosquito proofing is usually done by the construction and repair department of the station. However, recommendations should come from the malaria control officer and he should see that the work is done properly from the malaria control viewpoint.

Removing the nearby resting places of anopheline mosquitoes is frequently a desirable procedure. Most anophelines are night fliers, seeking protected resting places during daylight hours. Reducing the number of daytime resting places in and about a camp may so scatter the mosquitoes as to effect a reduction of the local adult mosquito population and the establishment of a barrier zone of lesser mosquito density around the living area. To this end, all grass and other similar vegetation may be cut or burned, and abandoned buildings and native huts destroyed. For some species of *Anopheles*, the daytime resting places have not been found. Actual investigations under local conditions should, therefore, precede any recommendation for the destruction of daytime hiding places.

Diversion of anophelines from camp areas may sometimes be accomplished by using domestic animals as a bait. Animals (cattle, horses, pigs) are placed around the camp or between the camp and known breeding places or sources of infection (native villages). If the animals are in barns or other shelters, these structures should be sprayed regularly to kill the attracted mosquitoes. The practical value of diversion by animals is debatable and dependent upon the habits of the anopheline vector in question.

PREVENTING MAN FROM INFECTING MOSQUITOES.

The native population usually constitutes the principal seedbed of malaria infection for mosquitoes and, therefore, whatever can be done to keep infected natives away from the area occupied by military personnel is good malaria control.

Camps should lie sufficiently far from native villages to prevent their associated infected vectors from feeding on the military personnel. All natives should be excluded from the zone of control around the station except those employed as laborers, and even these should be excluded after dark. It may be advantageous to give the natives malaria therapy in order to insure a safe and satisfactory control program.

The military population may also become the seedbed for infection. Special precautions should be taken to protect patients hospitalized for malaria from the bites of anopheline mosquitoes. Ambulatory carriers should be kept inside mosquito-proof quarters during the hours of darkness and otherwise kept from infecting the local anophelines.

NOTES

SURVEYING AND MAPPING

Some knowledge of surveying and mapping is essential in planning and carrying out a malaria control program. Suitable maps of the control area are indispensable for organizing the oiling and drainage program and for recording daily progress. Breeding areas, native villages, and areas occupied at night by troops should be clearly indicated, as well as adult collecting stations, larval-dipping stations, and orientation points such as roads and hills. Colored pins or flags may be moved about on a wall-map to indicate the current situation in regard to breeding, oiling, drainage, and the appearance of malaria cases. If satisfactory maps are not available, they must be prepared. In addition, an ability to conduct profile surveys of swampy or ponded areas is required in order to lay out an efficient drainage system.

METHODS OF MEASURING DISTANCE AND DIRECTION.

The branch of surveying employed in malaria control work is called plane surveying because the overall surface of the earth is considered to be flat rather than spherical. Since the actual curvature of the earth is only about 0.7 foot per mile, no appreciable error is introduced in surveys involving a radius of less than five miles. Surveying for malaria control is confined almost exclusively to measuring horizontal distances, determining the direction of horizontal lines and measuring vertical distances (elevations).

The horizontal distance between any two points is the air-line distance, not the distance that would be traversed in going up and down hill. Therefore, horizontal distances must be determined either by a series of horizontal measurements or by measurements along the slope taken in such a way that they can be converted to horizontal distances. Common methods of horizontal measurements used in malaria control work are: visual estimate, pacing, and chaining. Visual estimate, "taking distance by eye," is used only for rough approximations where speed is more important than accuracy and where visibility is not obstructed. Pacing or stepping off the distance between two points is a rapid method of determining horizontal distance and is sufficiently accurate for most mapping surveys. The length of stride must be known. In measuring distance by pacing, it is important to keep on a straight line and to maintain the same length of stride on even and on uneven ground. Where rises and depressions are traversed, allowance must be made to correct the slope distance to horizontal distance. With practice, it should be possible to pace distances with errors not exceeding 50 to 150 feet per mile. The amount of correction to make for different slopes can be learned only by experience, but the table given below will help the beginner. For every 100 feet measured up or down a slope, the true horizontal distance will be:

Rise or fall in ft. per 100 ft.	10	20	30	40
Horizontal distance - ft.	99.5	98.0	95.4	91.7

Chaining or taping is the measuring of horizontal distance by means of a tape. This method is used when pacing is not sufficiently accurate. Three kinds of tapes are commonly used: cloth, metallic cloth tapes having fine wires woven into the fabric to reduce stretching, and steel. The 100-foot length is most commonly used in engineering work. For convenience in calculation, engineers' tapes are graduated in tenths and hundredths of a foot, rather than in inches. The procedure in chaining the distance between two points is as follows:

1. Visible markers such as long stakes are set up at both points.
2. At the point of beginning one man (the head chainman) takes the 100-foot end of the tape and walks along the line the length of the tape.
3. A second man (the rear chainman) holds the zero mark at the point of beginning. The head chainman pulls the tape tight and the rear chainman motions him on line by sighting on the marker at the far end of the line.
4. When the tape is properly on line and the zero mark is on the beginning point, the head chainman puts a marker (nail or peg) in the ground at the 100-foot mark on the tape.
5. Both men now move ahead 100 feet and the procedure is repeated to mark a distance of 200 feet, and so on until the entire distance has been measured. It is important that an exact count be kept of the number of 100-foot measurements made.

When measuring on sloping ground, the tape must be held horizontally and the distance transferred to the ground by plumb lines. If the slope is so steep that the lower chainman cannot reach high enough to hold the tape level, the distance must be measured in shorter sections, 50-, 25-, or even 10-foot lengths.

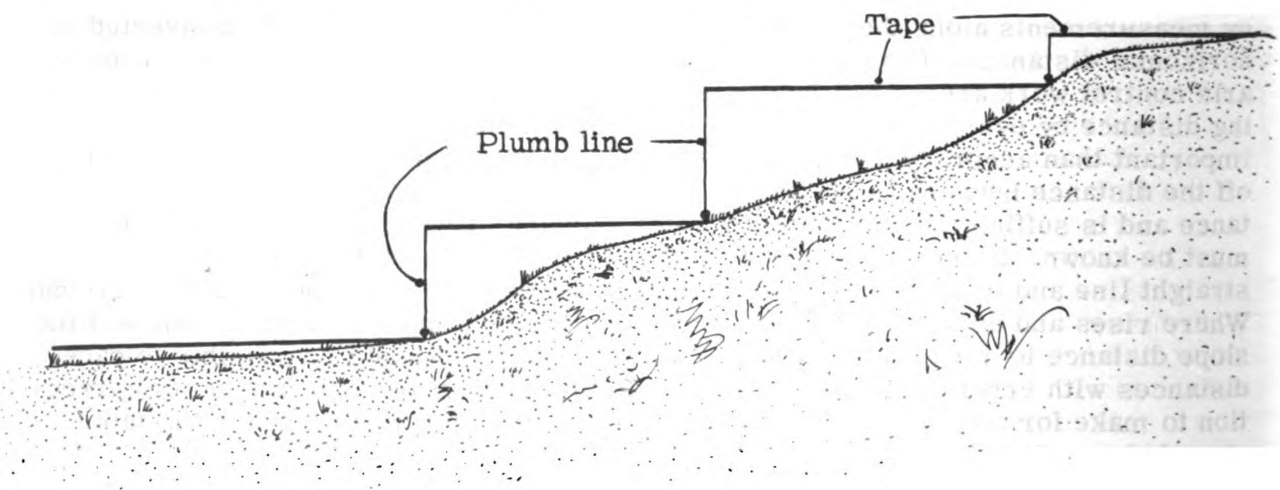


FIG. 104. Chaining horizontal distance on sloping ground.

When there is an obstacle on the line of measurement, vertical or horizontal offsets must be made. A vertical offset is made by plumbing; a horizontal offset,

by laying out ninety-degree angles around the obstacle. A ninety-degree or right angle can be laid out with a tape by making a triangle having the sides in the proportion of 3:4:5. For example, in figure 105, if the 0' and 48' marks are held at A, the 12' mark at C, and 28' mark pulled out so that a triangle is formed, the angle C will be a right angle.

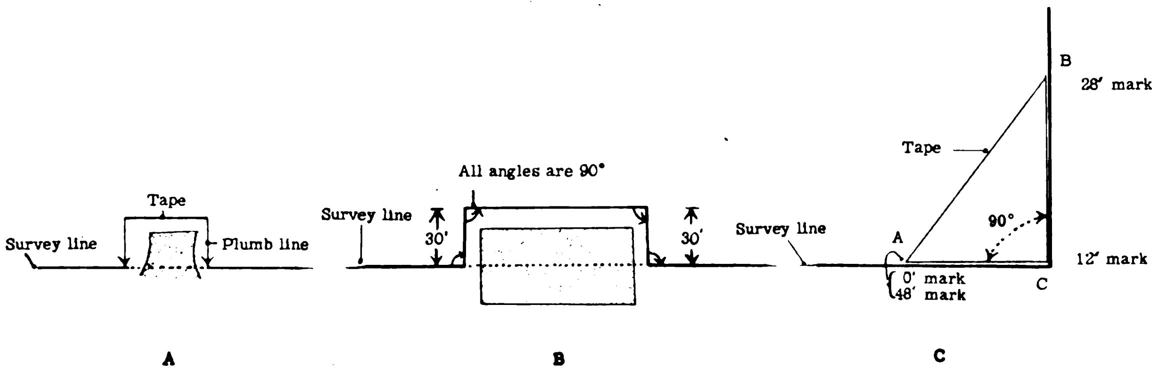


FIG. 105. A. Chaining over low obstacle. B. Chaining around building. C. Laying out a 90° angle by means of tape.

If a line is to be marked for further survey work, short stakes should be driven into the ground at the beginning point, at each 100-foot interval, and at such intermediate points as required. Stakes are driven vertically with the wide side across the line, and the distance from the starting point is marked with crayon on the rear face. The beginning point is marked 0+00, the stake at 100 feet 1+00. A stake at 165 feet would be marked 1+65; at 345.2 feet, 3+45.2. The points at even 100-foot intervals are called stations, those at intermediate points, pluses. The following are the most common mistakes and errors in chaining: poor alignment, not pulling the tape tight, careless plumbing, failure to use the correct zero mark on the tape, incorrect count of 100-foot lengths, and incorrect reading of the figures on the tape.

Measuring direction. Direction of a horizontal line is usually expressed as the angle of intersection with true north or magnetic north. True north is the direction from any point toward the North Pole and is used only in surveys requiring a high order of precision. Magnetic north is the direction indicated by the north-seeking pole of the horizontal magnetic needle. The angle of divergence (easterly or westerly) of magnetic north from true north is called magnetic declination. The amount and direction of declination varies from place to place, and in any one locality is subject to a small annual change which can be predicted from past records. On standard military maps, magnetic declination in the area represented is given graphically as shown in figure 106. In field work, direction is usually based on magnetic north because it can be quickly determined by means of a magnetic compass.

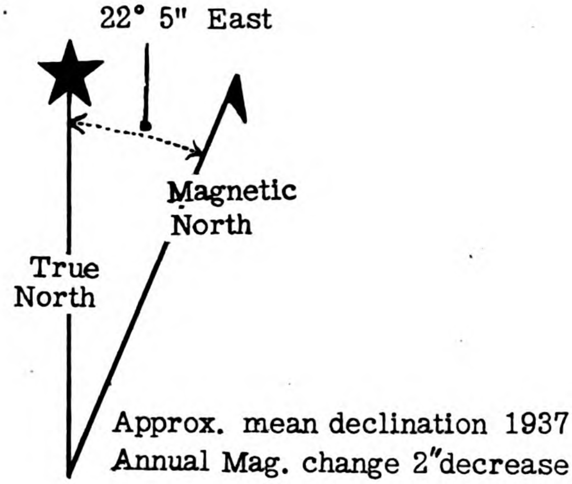


FIG. 106. Graphic representation of magnetic declination.

Pocket compasses are commonly used in surveying for malaria control work. The standard marching compass has a floating dial mounted on top of a magnetized bar. The dial has two scales of graduation, the outer scale is in mils (0 to 6400), the inner one in degrees (0 to 360). Both scales have the zero at the north point and the graduations increase in a clockwise direction. The mil scale is used only for certain military problems. To determine the direction of a line to an object, the object is sighted as shown in figure 107 B and the angle from magnetic north read through the lens on the rear sight. The graduations are such that the angle is always measured in a clockwise direction from magnetic north; thus, due east is 90 degrees, due south 180 degrees, and due west 270 degrees. A direction expressed in this manner is called a magnetic azimuth. When direction is taken by sighting back along the line (in the opposite direction from which the line is being run) the angle is called the back azimuth. The difference between the azimuth and the back azimuth of any line is always 180 degrees.

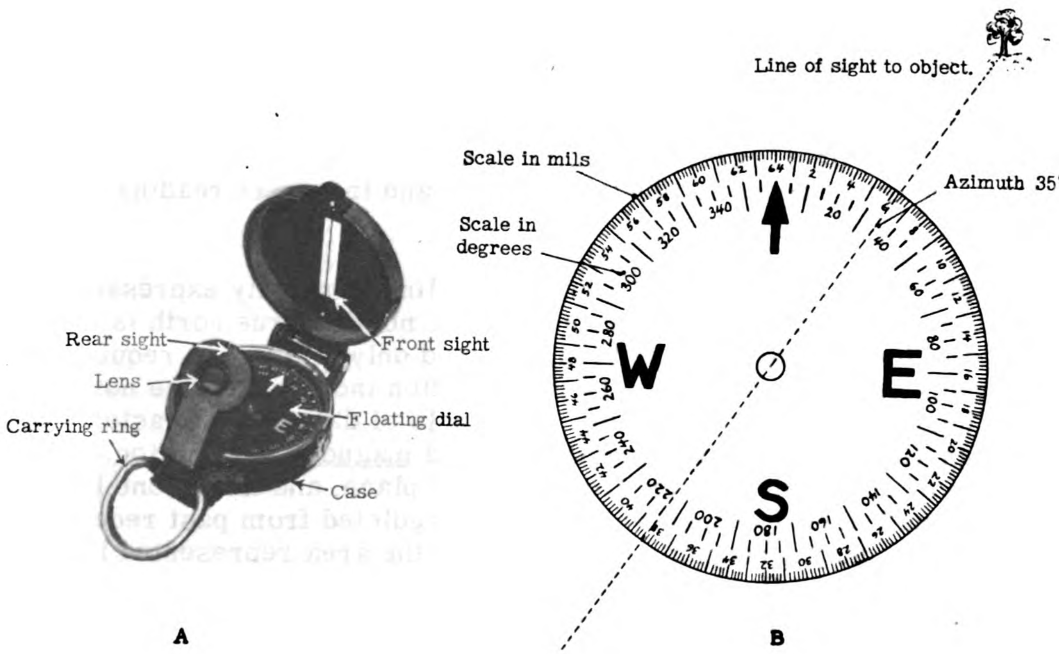


FIG. 107. Marching compass. A. Open for use. B. Diagram of floating dial and line of sight.

The surveyor's pocket compass differs from the marching compass in having the graduated scale fixed to the base of the case and the magnetized needle supported on a pivot above the scale. The circle is usually graduated in quadrants of 90 degrees from the north and south designations. The east and west designations are reversed from their normal positions so that when the sighting line is pointed toward an object the direction can be read directly from the graduation to which the north end of the needle points. The direction will be expressed as degrees east or west of magnetic north or magnetic south. Direction taken with a surveyor's compass is called the magnetic bearing.

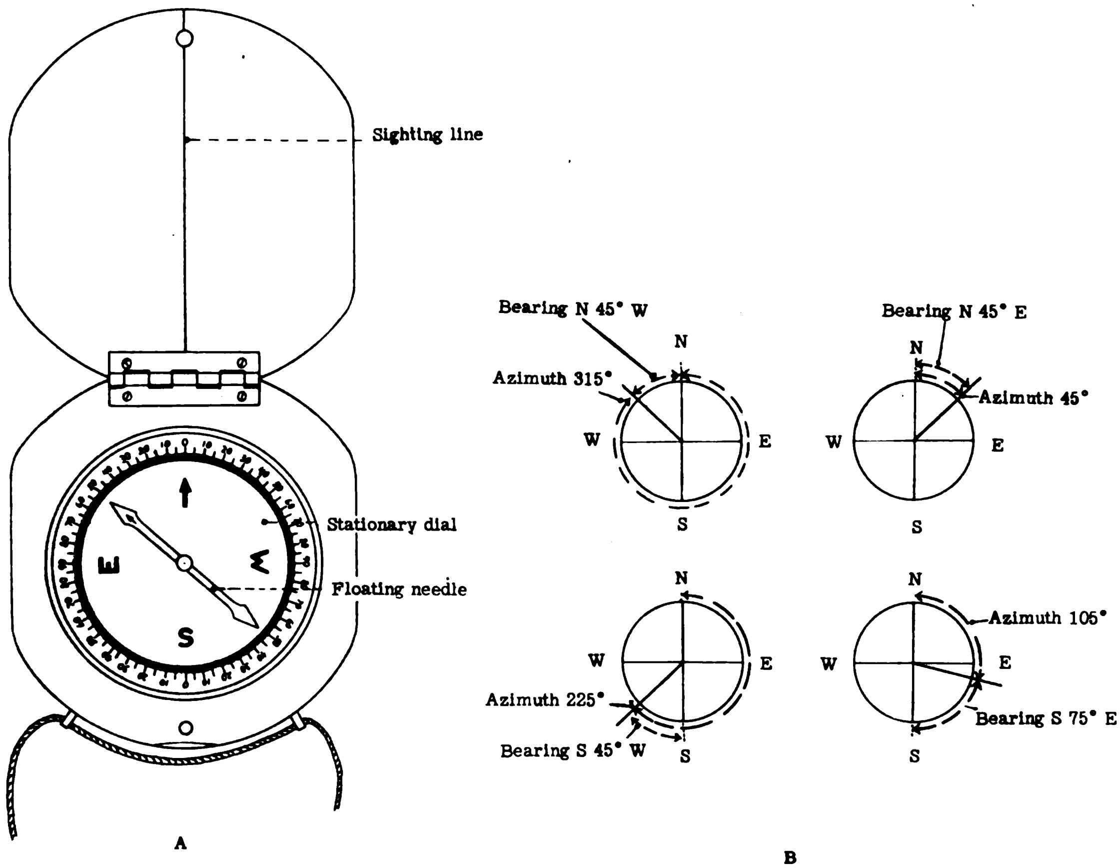


FIG. 108. A. Surveyor's compass.
B. Comparison of magnetic azimuth and magnetic bearing.

Magnetic compasses may be affected by local attractions; that is, the magnetic element may be attracted toward a nearby iron fence, steam line, or iron ore deposit. Compass survey lines must avoid sources of local attraction.

MAPPING.

A map is a graphical representation of a part or all of the earth's surface. It is a plane projection, thus representing a vertical or bird's eye view, and is made to scale so that all distances on the map are proportional to the distances they represent on the ground. The amount of detail shown and the accuracy with which a map is made should be determined by the purpose for which the map is to be used. All details of the terrain pertinent to malaria control should be shown. These should include swamps, water courses, ponds, ditches, campsites, and native villages. In addition to the necessary detail of the area represented, all malaria control maps should carry the following information:

1. Identifying title (Naval Advance Base X - Malaria Control).
2. Maker and date made (Made by John Doe, PhM2/c, 3-1-44).
3. Source and date of data (Aerial Photo No. 5704 or Compass and Pacing Survey,2-15-44).
4. Scale (Scale 1" = 500' ; or Representative Fraction* 1:10,000).
5. Orientation (Direction) - a line showing magnetic and/or true north with magnetic declination if known.
6. Legend - identification of symbols used.

By free-hand sketching, a rough map of comparatively small area can be made. The relative positions of various features of the terrain are merely estimated from some high point where vision is unobstructed and the details are sketched in proportionately on a sheet of paper. Maps made by this method are used for preliminary reconnaissance or in areas to be occupied only temporarily.

The compass and pacing survey is one of the most practical methods of field mapping. Distances are measured by pacing and directions determined by compass readings. The data are recorded as field notes from which the map is plotted on paper. The usual procedure is to run a traverse course which serves as a framework to which the various features of the terrain are tied by offset, radiation, or intersection.

Figure 109 represents a closed traverse survey. Starting at point A, the azimuth of the line AB was determined by sighting the line with the compass and the distance AB determined by pacing. The same was done for the lines BC, CD, DE, EF, FG, GA. The back azimuth of AB was sighted from B, of BC from C, etc., as a check on the azimuth readings. An offset was used to locate point 1. The distance along AB to the point opposite 1 was paced, a 90 degree angle turned from the traverse line, and then the distance along the right angle to 1 also paced. For points 100 to 200 feet from the traverse line the right angle can be estimated. Point 6 in

*Representative fraction 1:10,000 means that 1 unit of length on the map equals 10,000 of the same unit on the ground; 1 inch equals 10,000 inches; 1 foot equals 10,000 feet.

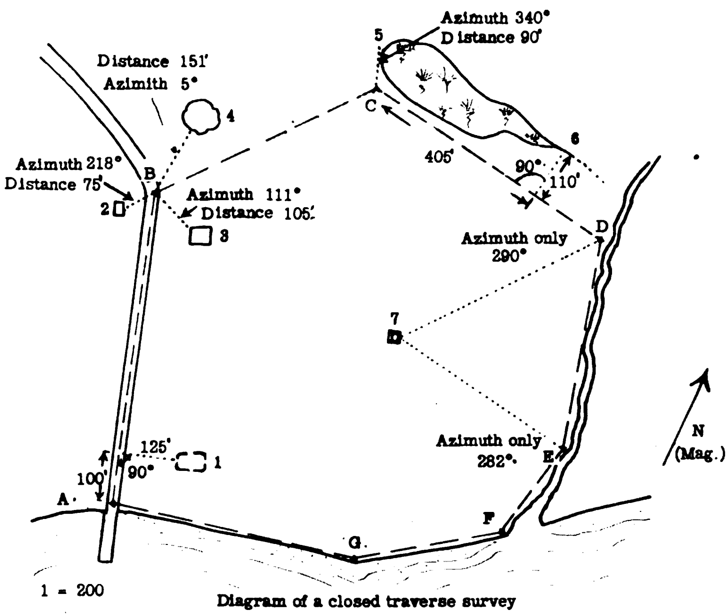


Diagram of a closed traverse survey

Points 1,6 - Located by offset
Points 2, 3, 4,5 Located by radiation.
Point 7 - Located by intersection.

FIG. 109. Diagram of closed traverse survey.

Measurement

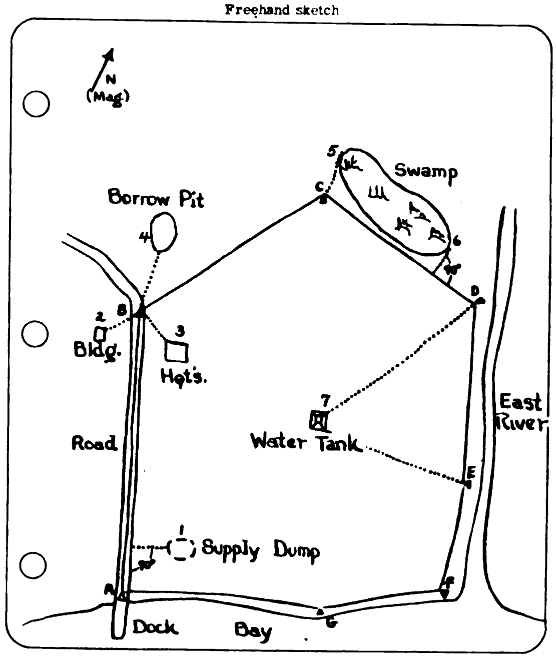
Compass and Pacing Survey
Dock Area - Advance Base X

John Doe
4-2-43

Station	Azimuth	Back Azimuth	Distance	
A - B	343°	165°	650'	
1	(offset)		100/125'	
B - C	39°	217°	497'	
2	218°		75'	
3	111°		105'	
4	5°		151'	
C - D	100°	279°	555'	
5	340°		90'	
6	(offset)		405/110'	
7(D)	219°		(intersection)	
D - E	165°	344°	452'	
7(E)	282°		(intersection)	
E - F	192°	12°	211'	
F - G	234°	53°	304'	
G - A	258°	78°	511'	

A

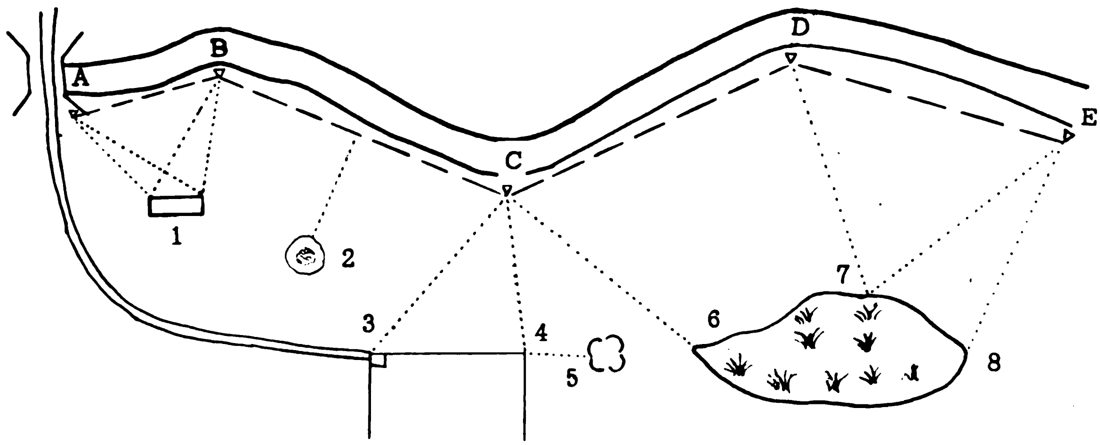
Freehand sketch



B

FIG. 110. Notes and freehand sketch of closed traverse survey.

the figure was located in the same way. Points 2 to 5 each were located by radiation; that is by taking both the azimuth and the distance from some point on the traverse to the point to be located. Point 7 was located by intersection. The azimuth to 7 was taken from the two known points D and E. The position of 7 would be fixed on the plotted map by the intersection of the lines of sight and therefore it would not be necessary to pace the distances to 7. An open traverse course does not return to the starting point. Open traverse is used to map water courses, road strips, etc. In areas where visibility is obstructed by jungle, mapping surveys may consist of a series of open traverses along water courses, all joined by cross traverses.



Open survey along a water course.

Point 2 located by offset from traverse line.
Point 5 located by offset from secondary point.
Points 3 4 6 8 located by radiation.
Point 1-7 located by intersection from traverse sections.

FIG. 111. Open traverse survey along a water course.

To make a map from the field notes it is first necessary to select a suitable scale. The scale should be large enough so that all the details given in the notes can be shown in proper relationship. Distances are then represented proportionally. Angles are calculated from the azimuths of the lines and are plotted by means of a protractor. In figure 112, for example, in calculating the deflection angle at B, the azimuth of BC (343°) is actually 85° greater than the azimuth of AB (258°). The deflection angle at C is 56°. Since the azimuth of BC is 343°, and therefore 17° west of north, 17° is added to the azimuth of CD (39°) giving a total deflection angle of 56°.

When a closed traverse survey is plotted, it will usually be found that the last traverse line will not end on the starting point. This is due to small unavoidable errors in reading the compass and pacing distance. The distance between the end of the final line and the starting point as plotted on the map is called the error of closure. If it is greater than 3 per cent of the traverse course, a gross error has been made and the survey should be repeated.

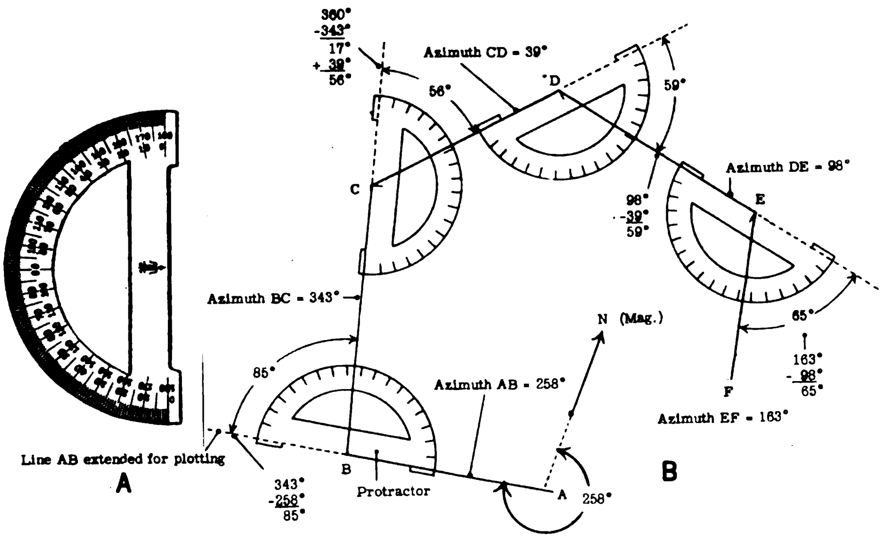


FIG. 112. A. Protractor. B. Method of calculating and plotting angles.

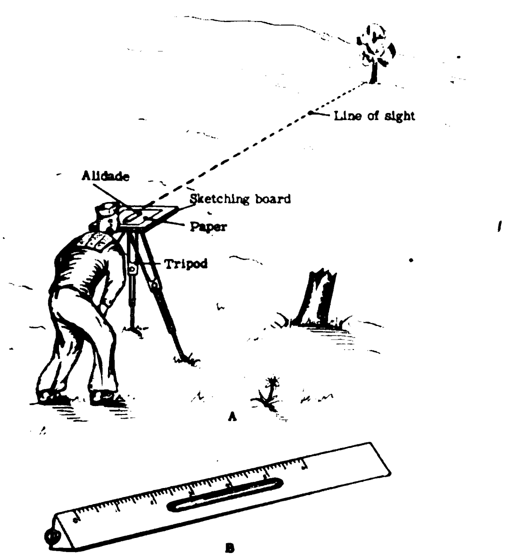


FIG. 113. A. Mapping with sketching board and alidade. B. Alidade.

The sketching board (plane table) survey is a method of mapping in which the data are plotted directly on the paper in the field. Thus the map takes form as the survey progresses. The equipment used consists of the following: a sketching board, a small plane table $12\frac{1}{2}$ x 15 inches, which attaches to a tripod by means of a locking screw; a triangular scale called an alidade, used for sighting and scaling distances; and a compass.

The procedure in general is the same as in the compass and pacing survey. Distances are measured by pacing, but direction is taken by sighting along the alidade instead of by compass readings.

Traverse lines are run as shown in figure 114 and are as follows:

At point A.

1. Attach the board to the tripod and fasten a sheet of paper to the board by means of thumb tacks or gummed paper.

2. Set up board and tripod solidly over point A (figure 114-1). Level the board by eye.

3. Mark a point a on the paper to represent point A on the ground and select a suitable scale.

4. Rotate the board so that the subsequent survey lines will fit on the paper; then lock the board so it will not turn.

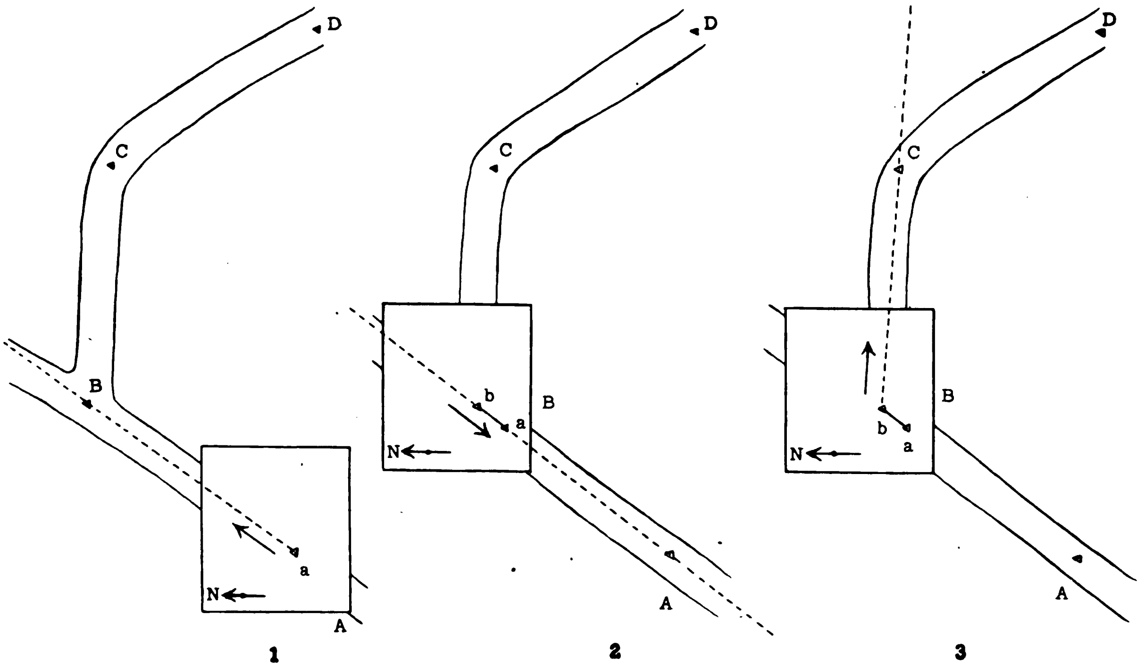


FIG. 114. Plotting traverse line by use of sketching board.

5. With the aid of the compass, draw near the edge of the paper a line representing magnetic north. This can be done by placing the compass on the board with the front sight flat on the paper, turning the compass so that the line of sight is on magnetic north. Then draw a line on the paper along the line of the wire of the front sight.

6. Place a pin or pencil point at point a on the paper. Place one edge of the alidade against the pin and sight to point B along the upper edge of the alidade, moving the alidade as necessary about the pin as a pivot.

7. With the alidade held in position, draw a line along the lower edge of the alidade from a toward B.

8. Pick up the board and pace distance AB.

At point B.

1. Set up the board at B (figure 114-2).Lay off the distance AB by means of the scale on the alidade. This will locate point b on the map, representing point B on the ground.

2. Lay the alidade with its ruling edge along ab. Rotate the board so that the line of sight on the sighting edge of the alidade is at A. This places the board in the same relative position as it was at A. Lock board so it will not rotate.

3. Proceed as at A, sighting C to get direction of the line bc to represent BC. Pace distance to C and scale off bc on the board.

Offset and radiation are carried out in the same manner as in the compass and pacing survey, except that direction is taken by sighting with the alidade instead of the compass.

Intersection is especially useful in this type of survey for locating points that are visible from two or more traverse points as shown in figure 115.

1. The board is set up over traverse point A. Point a on the paper represents the location of A on the ground.

2. Sight and draw in direction lines toward point B and X.

3. Pace the distance AB, set the board up over B, and scale ab to represent AB.

4. Lay the alidade with its ruling edge along ab and sight back to A by rotating the board. Lock the board when properly oriented.

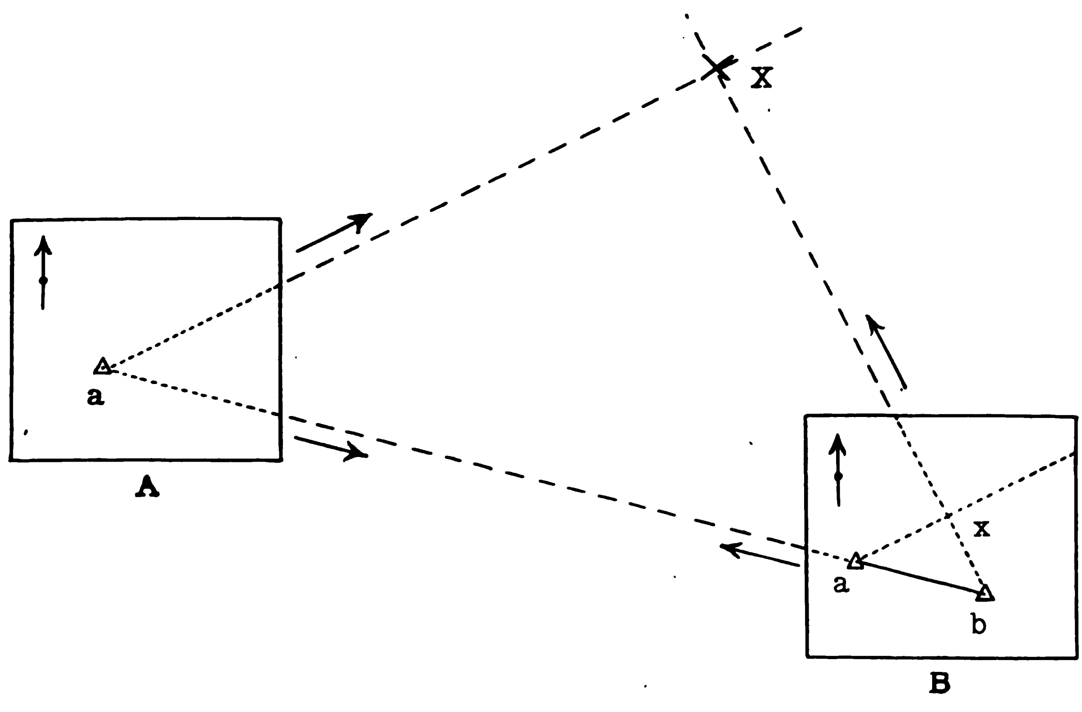


FIG. 115. Locating a point by intersection.

5. Using the alidade, sight and draw in the line bx. The point at which ax and bx intersect will represent point X.
6. If possible, sight to X from a third traverse point as a check.

Resection. It is sometimes desirable to set the board up at an unmapped point in a previously mapped area to insert additional detail. In case this is necessary, the location of the board may be established by one of the following methods of resection:

1. The compass and two-point method as shown in figure 116 A.
   a. The board with map attached is set up at the unmapped point X.
   b. Orient the board by placing the compass as shown in the figure and rotating the board until the north line on the compass coincides with the north line on the map, then lock the board.
   c. Place a pin at point a, rotate the alidade about a until the line of sight falls at A. Draw in the line as shown.
   d. Place the pin at b and similarly sight B and draw in the line.
   e. The intersection of the two lines x represents X - the point on the ground where the board is set up. This is the least accurate of the three methods given.
2. The tracing paper method, as represented in figure 116 B.
   a. Set the board up at X.
   b. Place a clean sheet of tracing paper over the map.
   c. On tracing paper, select any point x to represent X on the ground and draw radiating lines to three visible points, A, B, and C, previously mapped as shown in figure 116 B-1.
   d. Move the tracing paper about over the map (figure 116 B-2 and 3) until the direction lines on the tracing paper are directly over points a, b, and c on the map.
   e. Mark point x on the map by pressing the pencil point through x on the tracing paper.
   f. Check by sighting xaA and xbB.
3. The three-point method involves locating the position of X by a series of approximations, as shown in figure 116 C.
   a. The board is set up at X, oriented by eye or by compass, and locked.
   b. Extensions of lines aA, bB, and cC are sighted and drawn in. In most cases, the lines will not intersect at a point but will form a triangle, called the triangle of error (figure 116 C-1).
   c. Make an estimate (x1) of the correct position of the point. It will be either on the right or left of the triangle and distant from each of the three lines in direct proportion to the distances of the corresponding actual points (A, B, and C) from the occupied point (X).
   d. Place the alidade along x1a and rotate the board until the line of sight falls on A.
   e. Lock the board and again draw the lines. They will now intersect at a common point or form a second triangle of error smaller than the first one (figure 116 C-2).

f. If the lines do not intersect at a common point, make a new estimation (x2) of the location of the point from the second triangle.

g. Reorient the board as in step d, sight and draw in aA, bB, cC as in steps b and e. This time the lines should intersect at a common point (figure 116 C-3), giving the true location of x in relation to a, b, and c. This is the most accurate of the three methods of resection but requires more time and care than the other two. However, an experienced man can usually determine the correct point from the first triangle of error.

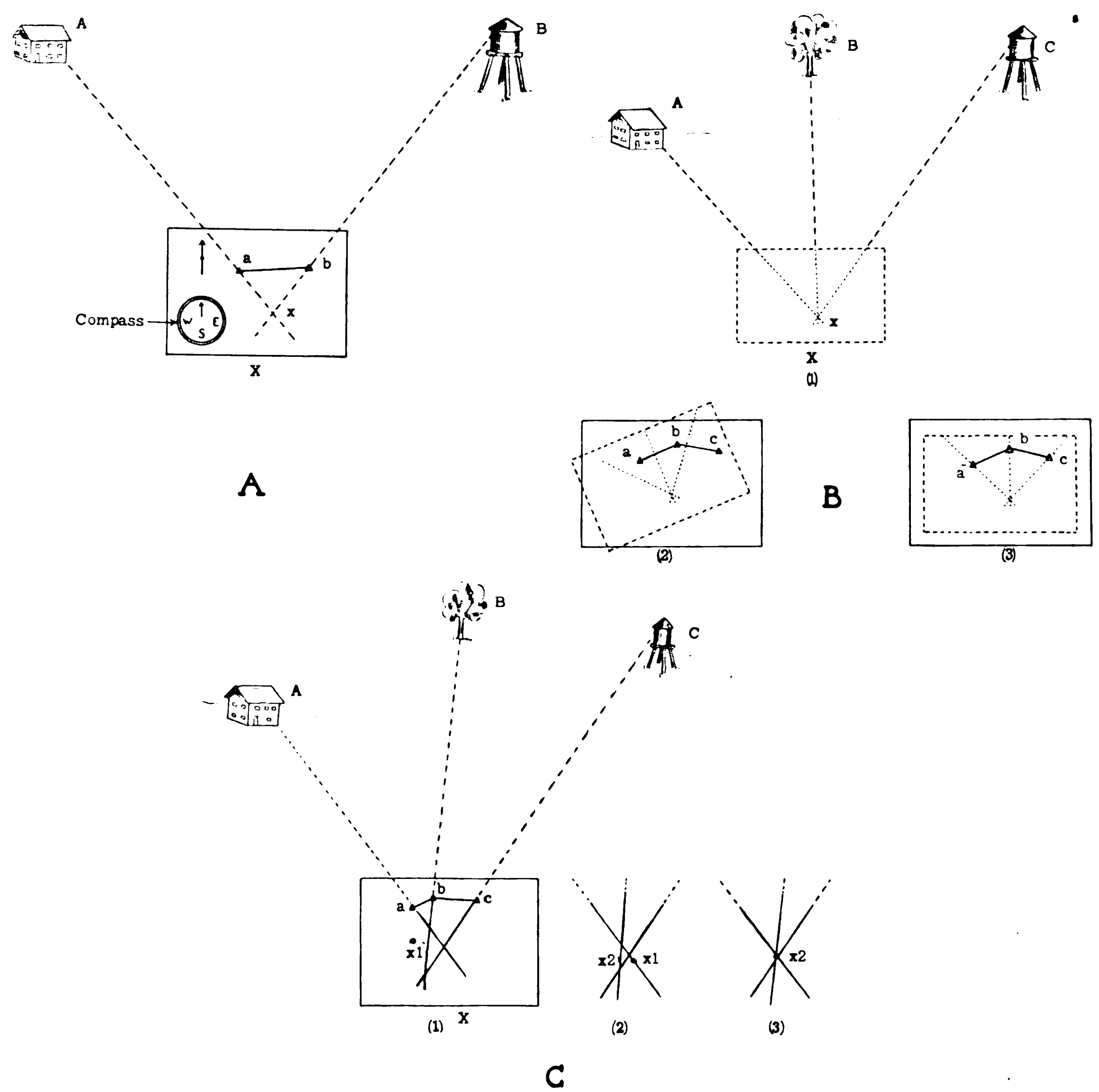


FIG. 116 Locating an unmapped point by resection. A. Compass and two-point method. B. Tracing paper method. C. Three-point method.

SURVEYING AND MAPPING

Aerial photographs are used for many different purposes in military operations. Frequently, they will serve as an excellent source for making malaria control maps. When necessary, additional details may be added by means of the surveying methods described above. Aerial photography has the following advantages over mapping surveys: maps can be made more quickly from photographs; photographs show a wealth of detail which could not be included in a field survey map; aerial photos can be made of areas that are not easily accessible from the ground; areas can be easily rephotographed to keep maps up-to-date. The disadvantages of aerial photography are: important features are often obscured by vegetation; important details are not emphasized; the relative position of objects may be inaccurate due to irregularities of line of flight and distortion produced by the lenses of the camera or by the tilt of the camera; accurate interpretation of details often requires special equipment and trained personnel.

The following are types of aerial photographs: vertical photos made with axis of the camera as nearly vertical as possible; oblique photos made with the axis of the camera deliberately tilted from the vertical (of limited value, the parts of the photograph not being on the same scale); aerial mosaics made by piecing together several photos which have been corrected so that they represent verticals with the same scale.

Orientation and scale are usually indicated on the margin of the photograph. However, when not given they can be determined as shown in figure 117. The procedure is as follows: select two points, A and B, on the terrain that can be easily identified on the photo; on the line AB on the ground determine the magnetic azimuth by compass and pace the distance; plot the magnetic north line as shown in the figure; measure AB on the photo and calculate the scale by the formula -

$$\text{Scale} = \frac{\text{Distance AB on ground}}{\text{Distance AB on photo}}$$

If tracing paper (a transparent drafting paper) is available, a map may be made from an aerial photograph by tracing off the desired details. If tracing paper is not available or if it is necessary for the map to be larger or smaller than the photograph, a reproduction may be made as shown in figure 118. The procedure is as follows: Rule off a grid of one or one-half inch squares on the photograph; number the columns of squares and letter the rows. On a clean sheet of paper rule off a grid in which the sides of the squares are larger or smaller by the proportion which the scale is to be increased or decreased. For example, if the scale of the photograph is 1" = 1,000' and the squares on the photograph are one inch on a side, then to make a map having a scale of 2" = 1,000' (1" = 500') make the squares on the paper two inches on a side. Number and letter the squares on the paper to correspond with those on the photo. In each square on the paper draw, in the same relative position, the detail that is in the corresponding square on the photo.

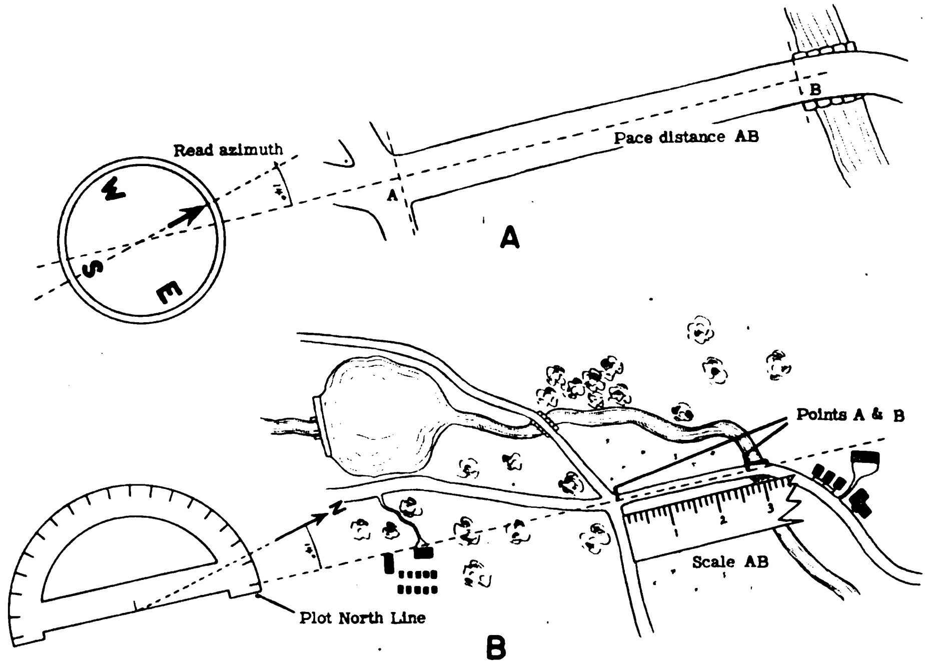


FIG. 117. Establishment of scale and orientation on aerial photograph. A. Measurements made on ground. B. Plotting and scaling on aerial photograph.

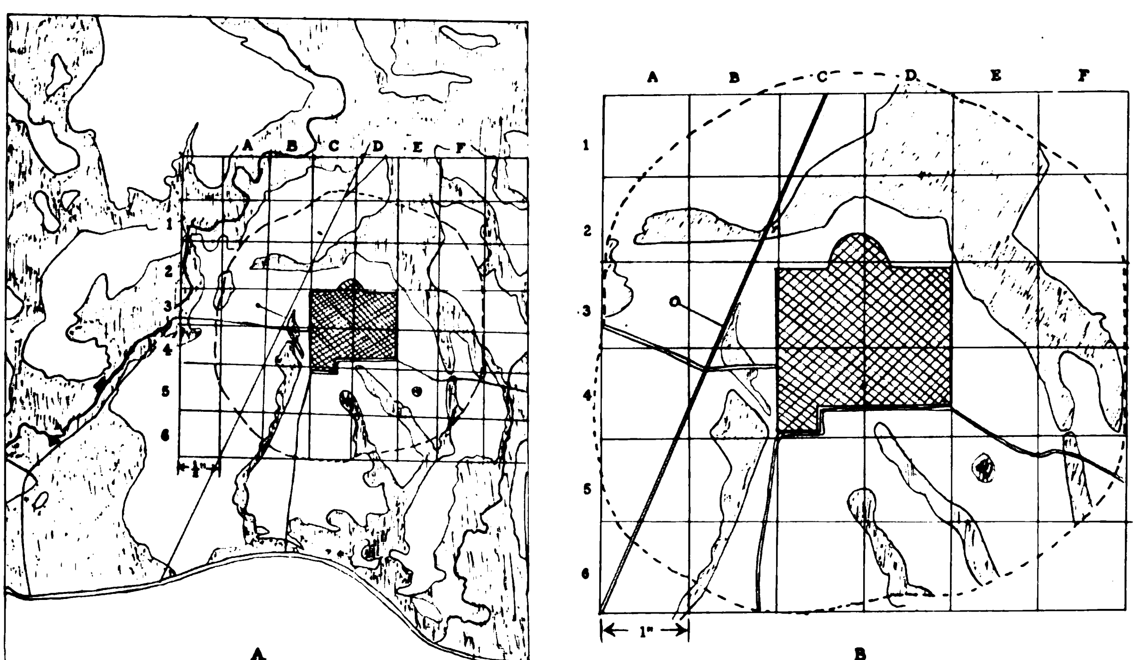


FIG. 118. Grid method of making an enlarged map from a portion of an aerial photograph. A. Aerial photograph. B. Enlarged map.

<u>Existing maps</u> of various types can be used as the basis for making a malaria control map. Maps with contour lines are especially useful. A <u>contour line</u> joins points having the same elevation. A clearer conception of a contour line may be had by imagining a valley partly filled with water to an elevation of 50 feet. The shore line of the lake will then be the 50-foot contour. If the level of the water is raised five feet, the new shore line will be the 55-foot contour, and so on. Contour lines may be spaced to show increases in height of 5 feet, 10 feet, and up to 500 feet. This spacing in regard to height is called the <u>contour interval.</u> Contour lines have the following characteristics: all points on any one contour line have the same elevation; every contour line closes on itself either within or beyond the limits of the map; contour lines can never cross each other except in the case of an overhanging cliff; they are close together when the ground is steep and far apart on gentle slopes; and they run up a valley, across the stream and back the other side.

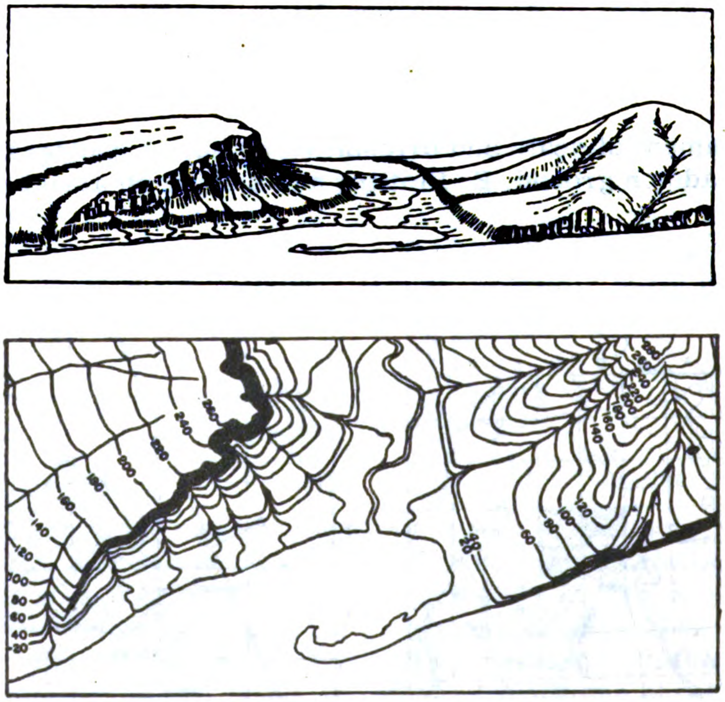


FIG. 119. Map showing contour lines obtained from actual ground elevations.

LEVELING.

In a level survey, vertical distances are measured to determine the comparative elevations of different points. Two types of level surveys are used in malaria control, profile surveys and cross-section surveys. In cross-section surveys, the volume of earth work is estimated. They are necessary only on large projects and should be under the direction of an experienced person. For further information, see any training manual or text on surveying.

In profile surveys, comparative ground elevations are established to determine the location and grade of drainage ditches. For ditches that are to be less than 400 feet long and on a good slope, the profiles may be made with chalk line and line level. The procedure is as follows:

1. Stakes are set up at 25-foot intervals on the center line of the proposed ditch.
2. A chalk line is run from post to post. Care must be exercised to pull the line tight to remove sag and to have the line as nearly level as possible. The line level should be reversed frequently to check.
3. Assign an assumed (arbitrary) elevation of 100.0 feet to the lowest point (outfall) and measure up to the chalk line to establish its comparative elevation.
4. Measure from the chalk line to the ground to determine the comparative ground elevations. These measurements should be made at the 25-foot intervals and at any intermediate points where there is a perceptible change in slope.

Measurements are recorded in note form as shown in the figure. When elevations are plotted to scale, the position of the ditch bottom can be determined and drawn in. The depth of the ditch at any point can then be obtained from the plotted profile.

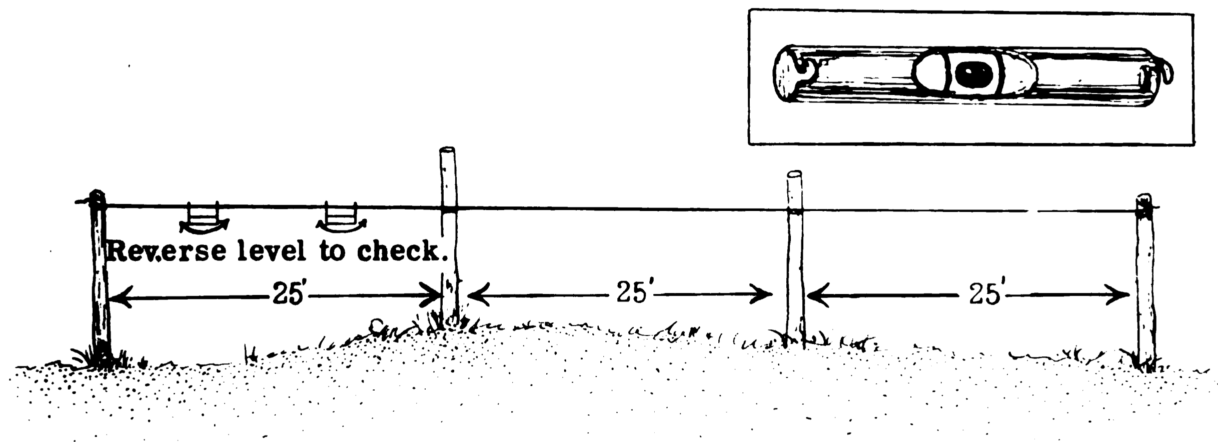


FIG. 120. Setting up chalk line for profile survey.

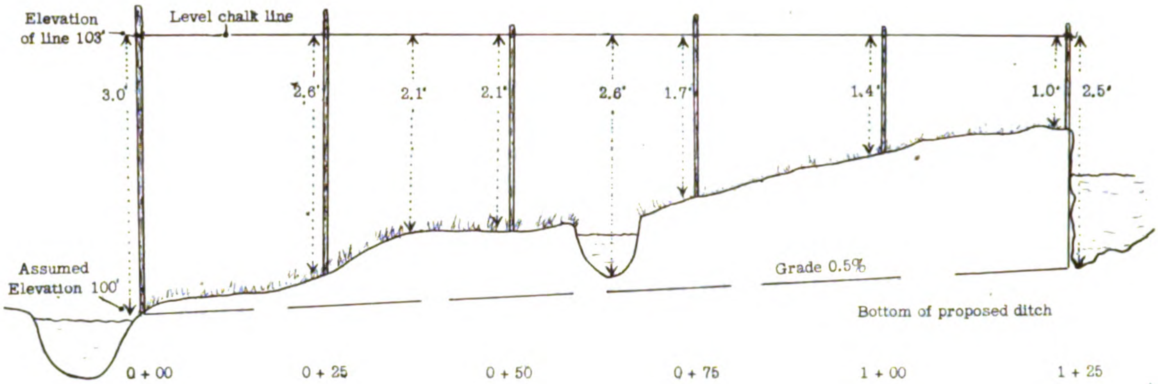


FIG. 121. Diagram of profile survey by means of chalk line, vertical proportion exaggerated to emphasize differences in elevation.

In making a profile survey of longer ditches, especially on flat land, an engineer's level and level rod should be used. The engineer's level consists of a telescope and spirit level supported on a base by a column and four leveling screws. The instrument is mounted on a wooden tripod when in use and so adjusted that the line of sight through the cross-hairs in the telescope is horizontal. This is a precision instrument. It should not be bumped or jarred, and the leveling screws should never be made so tight that they will not turn easily by hand. The leveling rod is made of wood and has the face graduated in tenths and hundredths of a foot.

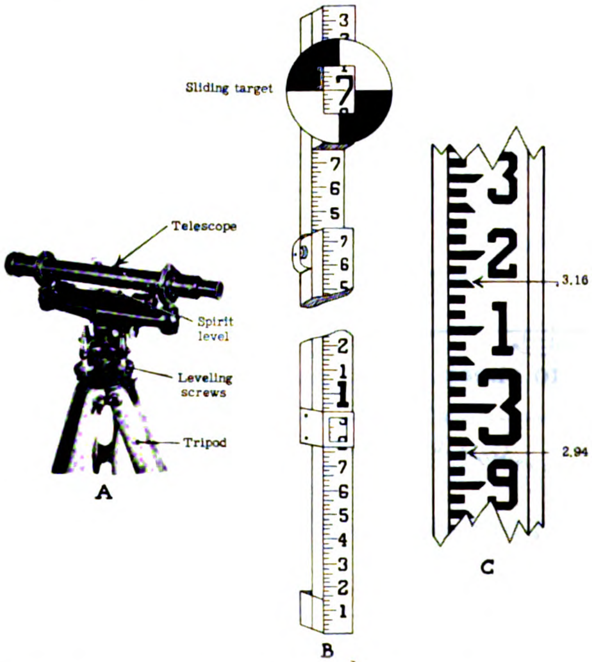


FIG. 122. Engineer's level and leveling rod.

The following terms are used in profile surveys made with an instrument:

1. Bench mark (BM) - a permanent or semi-permanent reference point having a known elevation. In drainage work, semi-permanent bench marks are frequently made by driving a long stake or pipe into the ground, leaving about eight inches above ground level. The elevation point is the top of the stake or pipe. This elevation may be the distance above sea level or above some other reference point. When no reference point is available, the bench mark may be assigned an assumed elevation, usually 100.00 feet. For profile surveys with an engineer's level, bench mark elevations are usually measured to the nearest 0.01 foot.

2. Turning point (tp) - a temporary bench mark used as a reference elevation when it is necessary to change the location of the instrument. It is usually a short stake driven into the ground.

3. Height of instrument (HI) - elevation of the line of sight of the instrument. Figure 123 B.

4. Plus sight (+s) - a measurement on the rod from a known elevation (BM or tp) to establish the elevation of the line of sight of the instrument. (Elev. of BM or tp) plus (+s) = HI. Do not confuse with a "plus" in chaining.

5. Minus sight (-s) - a measurement on the rod from a known elevation (HI) to establish the elevation of a point on the ground or of a new BM or tp. (HI) minus (-s) = Elevation.

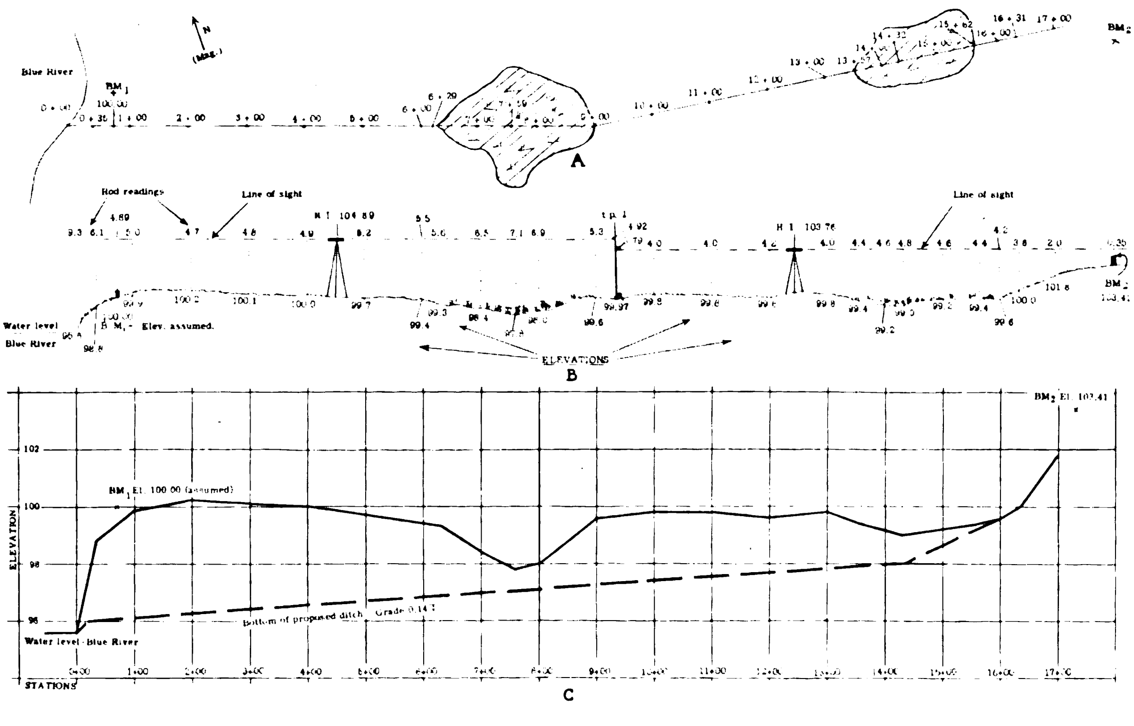


FIG. 123. A. Map of proposed drainage ditch. B. Diagram of profile survey for proposed drainage ditch. C. Plotted profile with grade drawn in.

The procedure in making a profile survey by means of an engineer's level is shown in figure 123. The steps are as follows:

1. The proposed ditch line is chained out, stakes being set at each station and at pluses wherever there is a perceptible change in the slope.

2. A bench mark is set near the beginning point, but far enough away from the ditch line so that it will not be disturbed by any future construction work. In the example given, an assumed elevation of 100.00 feet is assigned to this bench mark and it is designated as BM 1.

3. Assuming the optical range of the instrument used as about 500 feet, the level is set up at approximately the point shown in figure 123 B. It is usually desirable to set up a few feet to the right or left of the center line. The telescope is adjusted with the leveling screws so that the level bubble remains centered when the instrument is revolved.

4. A rod reading is taken on BM 1 to determine the HI. This is a plus sight; the elevation 00, the line of sight of the instrument, is now fixed at 100.00 feet (BM elevation) plus the rod reading.

5. Rod readings are now taken at all stations and pluses starting at 0+00 and progressing to 9+00. The rod is held on the ground beside the stake, not on top of the stake, because these readings are taken to determine the actual ground elevations. These are minus sights because they are measurements from the known elevation of the line of sight to an unknown elevation on the ground. Ground elevations are taken to the nearest 0.1 foot.

6. Assuming that the range of visibility of the instrument is limited to 500 feet, it will now be necessary to move the instrument. A turning point (tp 1) is therefore set in the vicinity of 9+00 and a rod reading taken on it to determine its elevation. This reading is also a minus sight.

7. The instrument is now moved to about half the remaining distance, set up as before, and a second reading taken on tp 1. This is a plus sight to determine the elevation of the new line of sight from the known elevation of tp 1.

8. Rod readings are now taken on the ground at each of the remaining stakes on the proposed ditch line. These are all minus sights.

9. At the end of the line a second bench mark (BM 2) is set, and a minus sight taken to determine the elevation of BM 2 in relation to BM 1.

A level survey must always be run back to the starting bench mark as a check against error. The procedure is as follows:

1. Change the HI at the last set-up by re-locating the instrument or by forcing the legs of the tripod a little further into the ground. Re-level the instrument.

2. Take a reading on BM 2 (a plus sight) to determine the new HI.

3. Set tp 2 somewhere in the vicinity of 9+00 and take a rod reading to determine its elevation. This will be a minus sight. (tp 1 may be used if it can be found easily.)

4. Move the instrument to a point approximately half way between tp 2 and BM 1 and level up for sighting.

5. Take a second rod reading on tp 2 to determine the elevation of the new line of sight (HI). This will be a plus reading.

6. Take a reading on BM 1 (a minus sight) and calculate elevations.

Profile Proposed Ditch on Blue River

Station	+ S	H. I.	- S	Elev.	
BM1	4.89	104.89		100.00	(Assumed)
0 + 00			9.3	95.6	
0 + 35			6.1	98.8	
1 + 00			5.0	99.9	
2 + 00			4.7	100.2	
3 + 00			4.8	100.1	
4 + 00			4.9	100.0	
5 + 00			5.2	99.7	
6 + 00			5.5	99.4	
6 + 29			5.6	99.3	
7 + 00			6.5	98.4	
7 + 59			7.1	97.8	
8 + 00			6.9	98.0	
9 + 00			5.3	99.6	
tp1			4.92	99.97	
	3.79	103.76			
10 + 00			4.0	99.8	
11 + 00			4.0	99.8	
12 + 00			4.2	99.6	
13 + 00			4.0	99.8	
13 + 57			4.4	99.4	
14 + 00			4.6	99.2	
14 + 32			4.8	99.0	
15 + 00			4.6	99.2	
15 + 62			4.4	99.4	
16 + 00			4.2	99.6	
16 + 31			3.8	100.0	
17 + 00			2.0	101.8	
BM2			0.35	103.41	
Check					
BM2	0.31	103.72		103.41	
tp2			4.10	99.62	
	4.91	104.53			
BM1			4.56	99.97	(Elev. 100.0 assumed)
			Error	± 0.03	

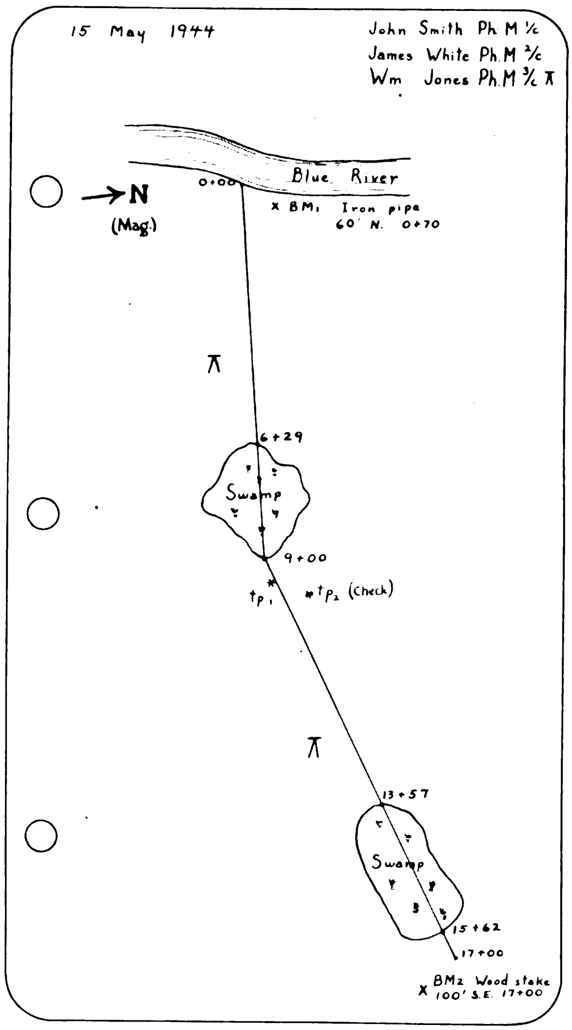


FIG.124. Field notes of profile survey.

In the field notes, figure 124, the difference between the assumed elevation of BM 1 and the elevation found in checking is 0.03 feet. This shows that no gross error has been made at the turning points or at BM 2. If the error exceeds 0.15 feet, the survey should be repeated. Note that only those errors in the framework (bench mark, turning points and elevations of line of sight) will appear in the check. Since no ground elevations are taken in the check, any errors at those individual points will not be evident. However, if the framework is correct, any gross error in a ground elevation will be apparent when the profile is plotted.

After the field work is completed, a profile is plotted from the field notes as shown in figure 123 B. In order to emphasize small differences in elevation, a much larger scale is used for vertical distances than for horizontal distances. The most common scales are horizontal - 1" = 100', vertical - 1" = 1', or 1" = 2'. When the profile is completed, the grade line (bottom) of the proposed ditch can be drawn in to fit the ground elevations. However, the type of soil, volume of water to be carried, location of tributary ditches and so on must also be considered in deciding on the best position of the grade line. A cut sheet (table of ditch depth) can now be prepared by scaling on the profile the distance from the grade line to surface of the ground (figure 123 C).

To transfer the cut sheet data to the ground, either batter boards or T's are used as shown in figure 125. When batter boards are used, the tops of all the boards are set the same distance above the proposed grade. Thus the string connecting the boards will make a line parallel to the grade line and can be used as a base for measuring down to grade at any point. When the T's are used, the upper edges of all the cross pieces are set the same distance above grade (bottom of proposed ditch), and the line of sight between the upper edges of the cross pieces serves the same purpose as the string line on the batter boards. The T's are less accurate than the batter boards but are more quickly set up.

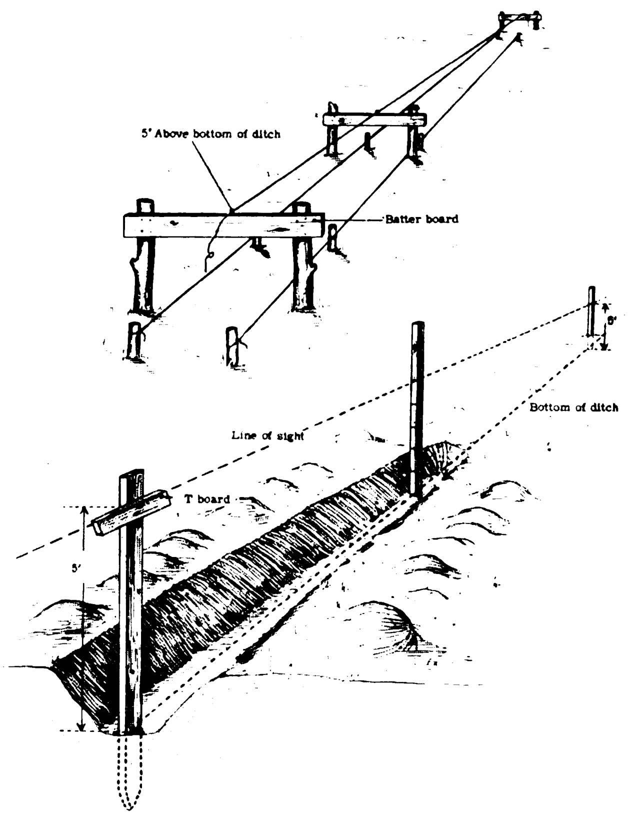


FIG. 125. Use of batter and T boards to determine the grade line of a ditch.

SECTION IV

ENTOMOLOGICAL TECHNIQUES

COLLECTION AND PRESERVATION OF ARTHROPODS

Since the specific identification of medically important arthropods is often very helpful or even essential in determining which measures should be used in their control, methods of collecting and preparing such specimens for identification are included here. Because of the enormous numbers of species, exact identification can best be made by a specialist highly trained in the identification of a particular group of arthropods. If specimens are collected which seem to be of medical importance, a tentative identification can be made by using the keys and figures in this manual. For more detailed and accurate identification, specimens should be sent to the Medical Officer in Command, Naval Medical School, Bethesda, 14, Maryland.

Directions for collecting, preparing, and shipping such materials are outlined below. Do not send live specimens through the mails. In shipping specimens mounted on slides or contained in vials of alcohol, special care must be taken in packing to prevent breakage. In the tropics particular care should be taken to store insects in dry containers. Mold and insect pests will soon destroy a collection if it is not properly cared for. Salve tins or pill boxes, packed with adults as indicated below, should be enclosed in mailing tubes or other sturdy containers for shipping. If pinned adults are sent, the pins must be forced firmly into place and the mounting box must be enclosed in excelsior within another sturdy shipping box and plainly labeled "Fragile." All shipped material should be accompanied by complete data as to locality, date, elevation, collector's name, and other pertinent information as to habits, habitat, abundance, and distribution. As far as possible, reared specimens should be accompanied by associated larval and pupal skins.

MOSQUITOES.

Adult mosquitoes are usually collected at catching stations, in bait or light traps, or from various daytime resting places. A chloroform tube is commonly used in their capture. Such a tube can be easily prepared by placing a half inch of cut rubber bands or other rubber scraps in the bottom of a large shell vial or test tube, saturating the rubber with chloroform, covering with a plug of crumpled paper or cotton, and topping with a circle of stiff paper. Various types of suction apparatus are used for taking specimens alive or in large numbers.

Minuten nadeln may be used to pin freshly killed adults as shown in the accompanying sketch. The adult mosquitoes may also be glued to paper points, using Duco household cement, orange shellac, or some other adhesive. Dried specimens should be relaxed before being mounted, care being taken not to rub the specimens or break off the more fragile body parts.

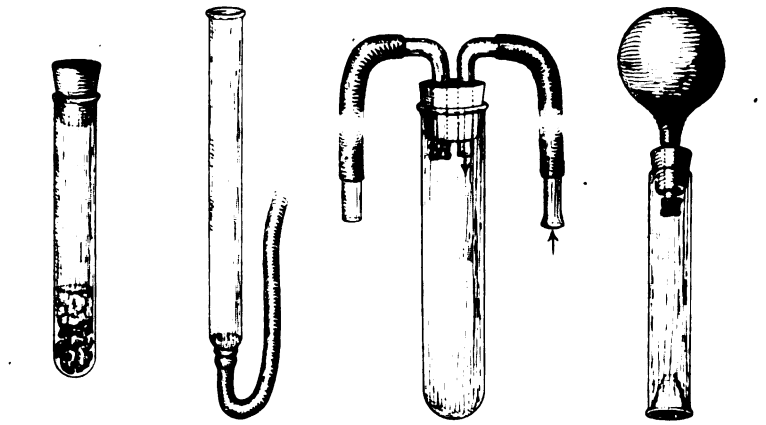


FIG. 126. Aids in collecting adult mosquitoes. A. Chloroform tube. B, C, and D. Types of suction collecting tubes or aspirators.

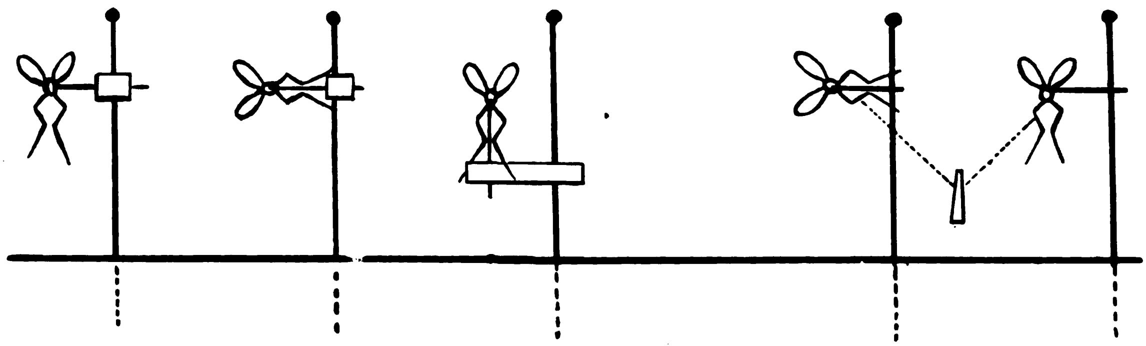


FIG. 127. Preserving adult mosquito specimens for study.

Unmounted adults can be placed between layers of glazed cotton, cellucotton, or cleansing tissue in pill boxes or salve tins of appropriate size. Plain cotton is objectionable because the specimens become entangled with the fibers and breakage results when they are removed for mounting. The cellucotton expands and contracts, depending upon the humidity; therefore, in humid areas in the tropics, care should be taken to cut the sections of this material large enough to fit snugly even when shrunken from drying. If napthalene or paradichlorobenzine is added to prevent the development of mold or the attack of insect pests, it should be used sparingly in fine crystals in the bottom of the pill box and should not be allowed to come in contact with the specimens.

A study of male terminalia is sometimes necessary for specific identification. The terminalia must be cleared and mounted on slides for microscopic examination. Methods of preparation are described by Ross and Roberts (1943) in the "Mosquito Atlas," Part I, page 5; and by Komp (1942) in "A Technique for Staining, Dissecting, and Mounting the Male Terminalia of Mosquitoes," Public Health Reports, volume 57, number 36, pages 1327-1333.

Fertile anopheline eggs can often be obtained by confining females in a small cage over a dish of water or in a small vial with a few cubic centimeters of water in the bottom. The eggs can be easily recovered by filtering, and the sheets of moist filter paper with the eggs can be packed between layers of damp cotton in a container sealed with paraffin. Eggs packed in this way will remain viable for several days and can be transported to a central laboratory for rearing. A sample batch of eggs on a narrow strip of moist filter paper can be preserved in formaldehyde fumes in a tube tightly corked and sealed with paraffin. A cotton plug saturated with ten per cent formalin should be placed in the bottom and another dry plug should be placed about one centimeter above it, so that the eggs are not directly wetted with formalin. The novocain tube illustrated below is very satisfactory for this method of egg preservation.

Mosquito larvae are usually found floating at the surface of the water where they can be collected by skimming the water with a cup or dipper. The larvae can be removed with a wide-mouthed dropper or spoon and returned to the laboratory for rearing, identification, or preservation. They can be reared on scrapings of dog biscuit, yeast, or crushed toast crumbs, care being taken to change the water frequently. For quick identification, the examination of a freshly killed larva in a drop of water on a slide is often sufficient. Details are much more readily seen when the specimen is cleared and permanently mounted on a slide. For careful study, all mosquito larvae should be prepared in this way.

Before mounting or preserving mosquito larvae in alcohol, the specimens should be killed in a manner to avoid shrinkage and distortion. Single larval specimens in a drop of water can be killed by holding the slide over a desk lamp for a short time. Larger numbers can be killed by dipping them in hot (not boiling) water for 15-20 seconds. For storing, specimens should be run through 50 per cent, then 70 per cent alcohol, and placed in vials with cotton plugs to prevent movement and breakage. Very convenient containers can be made from empty novocain tubes discarded by dental units.

FIG. 128. Novocain tube for storing mosquito larvae and pupae in alcohol.

A number of different media and techniques may be used for mounting mosquito larvae and other small arthropods on slides for microscopic study. These various materials and techniques, with their advantages and disadvantages, will be discussed below.

Chloral-gum media: The use of Berlese's formula, or one of its several modifications, is advantageous since no dehydration of the specimen in alcohol is necessary. This reduces handling of larvae to a minimum and lessens the likeli-

hood of mechanical injury. Some difficulty, however, has been experienced with the permanence of these mounts. Specimens can be killed and mounted directly from water. Mosquito larvae can be killed on a slide as described above, excess water drained away with filter paper, gauze or paper toweling, and one or two drops of the medium placed on the specimen. Small fragments of cover slip or narrow strips of paper, previously saturated in the medium, can be placed on either side of the specimen to prevent crushing by the cover slip. The last few segments of culicine larvae should be pinched off with a needle to allow the breathing tube to appear in full lateral view. The slide should be kept in a horizontal position for several weeks until the medium hardens. The edges of the cover slip should then be ringed with some sealing agent such as clarite, isobutyl methacrylate, cellulose cement, black asphaltum sealing material, or Duco household cement.

Gater's modification of the chloral-gum formula is commonly used. It can be prepared as follows:

Gum arabic (gum acacia)	8 grams
Distilled water	10 cc.
Chloral hydrate	75 grams
Glycerin	5 cc.
Glacial acetic acid	3 cc.

The gum arabic is dissolved in water, the action hastened by keeping the water warm, and the other ingredients are added in the order given. The thick solution can then be strained through several thicknesses of clean muslin, if necessary. Other modifications have been recommended, but the above formula seems the simplest to prepare and its ingredients are available in most laboratories.

Polyvinyl alcohol-phenol-lactic acid medium: Another rapid method for mounting mosquito larvae and other small arthropods without clearing and dehydration in alcohols is through the use of a medium prepared as follows:

Polyvinyl alcohol stock solution	56 per cent
Phenol	22 per cent
Lactic acid	22 per cent

The stock solution is prepared by dissolving the powdered alcohol (Dupont-Grade RH-349A) in water until the solution becomes as viscous as thick molasses. This stock solution becomes clear on standing, or clearing can be hastened by heating over a water bath. Specimens can be mounted in this medium as described for chloral-gum and the cover slips ringed in the same way for more premanent slides.

Canada balsam, clarite, and isobutyl methacrylate: For mounting specimens in media which have xylol as a solvent, it is necessary first to dehydrate in 50, 70, and 95 per cent alcohol. The specimens should then be cleared in clove oil, carbol-xylol (3 parts xylol and one part melted phenol crystals), or absolute alcohol followed by xylol. The specimens should remain in the various changes at least 15-20 minutes. After clearing, they may be mounted in balsam, clarite, or isobutyl methacrylate. With balsam and clarite, hardening of the media may take several days. Isobutyl methacrylate, on the other hand, dries very quickly and slides can be used in a few

hours; ringing or sealing is unnecessary. All slides should be fully labeled with locality, date, and collector.

OTHER NEMATOCEROUS DIPTERA.

Specimens of the smaller Diptera of medical importance - - Ceratopogonidae, Psychodidae, and Simuliidae - - are best preserved in 70 per cent alcohol in the field. *Phlebotomus* adults can later be mounted on slides for careful study; but if *Culicoides* are mounted in this way, it is often difficult to make out the characteristic color markings on the wings. *Simulium* adults can also be preserved in alcohol and later dried for mounting. In all three of these groups, specimens may also be preserved dry, as described for mosquito adults, and later mounted in various ways for more detailed study.

MITES.

Specimens may be preserved in alcohol and subsequently mounted on slides. For temporary mounts, they may be pipetted onto a glass slide and covered with a drop of 50 per cent alcohol and gently heated over an alcohol lamp. This results in perfect clearing and extension of the specimen so that the finest details of both dorsal and ventral surfaces can be seen.

For permanent mounts, specimens are transferred to a drop of the chloral-gum medium, covered, heated very gently until bubbling begins, and put aside to set. Specimens can be mounted directly from life, but alcohol specimens must first be washed in distilled water or lactic acid to remove the alcohol. The chloral-gum medium has the advantage of speed in clearing and mounting, and specimens may be soaked off in water and remounted at any time.

The following modification of the usual chloral-gum formula has been recommended for mites:

Water	35 cc.
Chloral hydrate	30 grams
Gum arabic	20 grams
Glycerine	12 cc.
Glucose syrup	3 cc.

TICKS.

These arachnids can be picked from their host animals or they can be collected by "flagging" - drawing a rough flannel cloth over the grass and shrubbery in an infested area - and then collecting any ticks that attach to the "flag." They may be preserved in 70 per cent alcohol or cleared and mounted on slides. If slides are to be made, the ticks can be fixed in an extended position by pressing them gently between two glass slides while they are killed by dipping in hot water.

They can be kept in 70 per cent alcohol, cleared in KOH, dehydrated in alcohols, and mounted in balsam, clarite, or isobutyl methacrylate, as described for fleas.

FLEAS.

These insects may best be collected from small animals by etherizing the host in a bell-jar or other large container and picking up the stupefied fleas that attempt to escape. If the host is killed, it should be dropped immediately into a tight cloth bag to prevent the escape of the fleas that desert the animal as soon as it begins to cool. Dogs or cats may be dusted with ground pyrethrum or derris root, and the fleas picked up from papers spread on the floor under the animal. Specimens may be preserved in 70 per cent alcohol or mounted on slides for specific identification by following the procedure outlined below:

1. Drop living fleas or preserved specimens into 10 per cent KOH and allow to remain a day or two until cleared sufficiently.
2. Transfer to water in a watch glass containing a few drops of HCl; allow to remain one half hour.
3. Dehydrate by running through 50 per cent alcohol, and
4. 95 per cent alcohol for one half hour each.
5. Clear in beechwood creosote for one hour, or run through several changes of absolute alcohol and clear in clove oil or xylol.
6. Mount on slides in balsam, isobutyl methacrylate, or clarite.
7. Label fully, including host animal, locality, date, and collector's name.

MISCELLANEOUS ARTHROPODS.

Spiders, scorpions, centipedes, millipedes, lice, bedbugs, maggots and other larvae, nymphs and other soft-bodied insects may be preserved in vials of 70 per cent alcohol, the corks paraffined to prevent loss through evaporation. If a small amount of glycerine is added to each vial, the specimens will not become dry and shrunken should the alcohol be accidentally lost. If the vials are kept upright, the corks will remain dry and stay in good condition much longer than otherwise. The larger, hard-bodied adult insects may be pinned and labeled carefully and stored in Schmidt boxes or cigar boxes. Care should be taken to keep specimens dry and to prevent mold and damage by insect pests. The addition of a small amount of naphthalene flakes or paradichlorobenzene to storage boxes will prevent such damage.

DISSECTION OF MOSQUITOES FOR MALARIA PARASITES

MATERIALS AND APPARATUS:

1. Glass slides.
2. Small cover slips.
3. Curved forceps.
4. Needles, points flattened and sharpened, mounted in suitable holders.
5. Safety razor blade.
6. Small triangles of filter paper.
7. Physiological saline.
8. Physiological saline deeply tinted with methylene blue.
9. Pipettes or droppers.

PROCEDURES: In selecting mosquitoes for dissection, avoid using those containing recently ingested blood or those in which the abdomen is distended by the fully developed ovaries. Recently engorged mosquitoes will show a dark, swollen area in the ventral abdominal region. These may be kept in tubes with moist cotton plugs or in humid cages for 48 hours to allow digestion of the blood meal. If it is necessary to examine a recently engorged mosquito, carefully prick the abdomen and squeeze out the blood.

1. Kill the mosquitoes with chloroform, only one or two at a time.
2. Identify and record the species.
3. Remove the legs and wings with needles.
4. Place the insect on a slide and sever the abdomen with a clean cut of the razor blade.
5. Transfer the head and thorax to a drop of tinted saline on another slide.

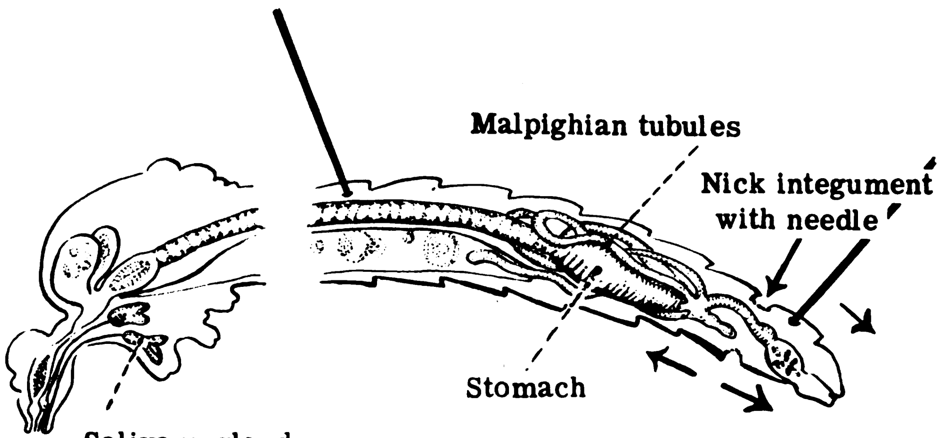


FIG. 129. Dissection for malaria parasites.

DISSECTION OF MOSQUITOES FOR MALARIA PARASITES

DISSECTION OF STOMACH:

1. Place the abdomen on a black background, illuminate with a strong direct light.
2. Immerse in a large drop of physiological saline.
3. With the needles, nick the integument on both sides just in front of the terminal segments, as shown in the above figure.
4. Place the point of one needle on the terminal segments, the other on the integument at the anterior end; and by gentle traction, draw out the stomach with the attached Malpighian tubules and ovaries.
5. Remove most of the saline with a triangle of filter paper.
6. Cut off the Malpighian tubules close to their attachments and the gut posterior to the stomach. Sweep away with the ovaries, eggs and other debris.
7. Add fresh saline and gently lower a cover slip onto the stomach.
8. Withdraw sufficient saline so that the stomach flattens out, and examine under low and high power of a compound microscope.
9. The stomach can be rolled over by adding saline and gently moving the cover slip.
10. Watch for oocysts on the outside wall, examining for protrusions which may appear as follows:
    a. Young oocysts - clear, round, or oval bodies, more refractile than stomach cells, containing minute pigmented granules, measuring 6-12 microns in diameter.
    b. Older oocysts - denser than the stomach, with clumps of pigment.
    c. Mature oocysts - measure 30-80 microns in diameter, appear finely striated and contain enormous numbers of refractile, spindle-shaped sporozoites that are 12-14 microns in length.

A positive diagnosis should not be made unless pigment granules are visible within the object, since small protrusions of the stomach membrane or fat cells may simulate immature oocysts. It must also be remembered that it is impossible to distinguish between bird and human malaria in the mosquito.

DISSECTION OF SALIVARY GLANDS:

1. Place the head and thorax in the blue tinted saline against a white background, with the head toward the right.
2. Hold the thorax with the left needle, drawing the head down and forward with the right.
3. Usually the salivary glands will come out in a tag of tissue attached to the head. They may be recognized by their trilobed form, shining appearance, and deep blue tint. If they do not come out, they may be recovered by tearing apart the tissues near the neck attachment.
4. Isolate the salivary glands, remove the debris, and add plain saline and a cover slip.
5. Remove any excess saline and rupture the salivary glands by pressing the cover slip lightly with a needle.

6. Examine for sporozoites under high power (500 diameters). Sporozoites are slender, refractile, spindle-shaped bodies, which sometimes move with a slow end to end motion. The final test is to remove the cover slip, allow the saline to dry, and stain with Giemsa or Wright's stain. Under the oil immersion lens, the sporozoites should appear as slender blue-stained spindles with a central red chromatin dot.

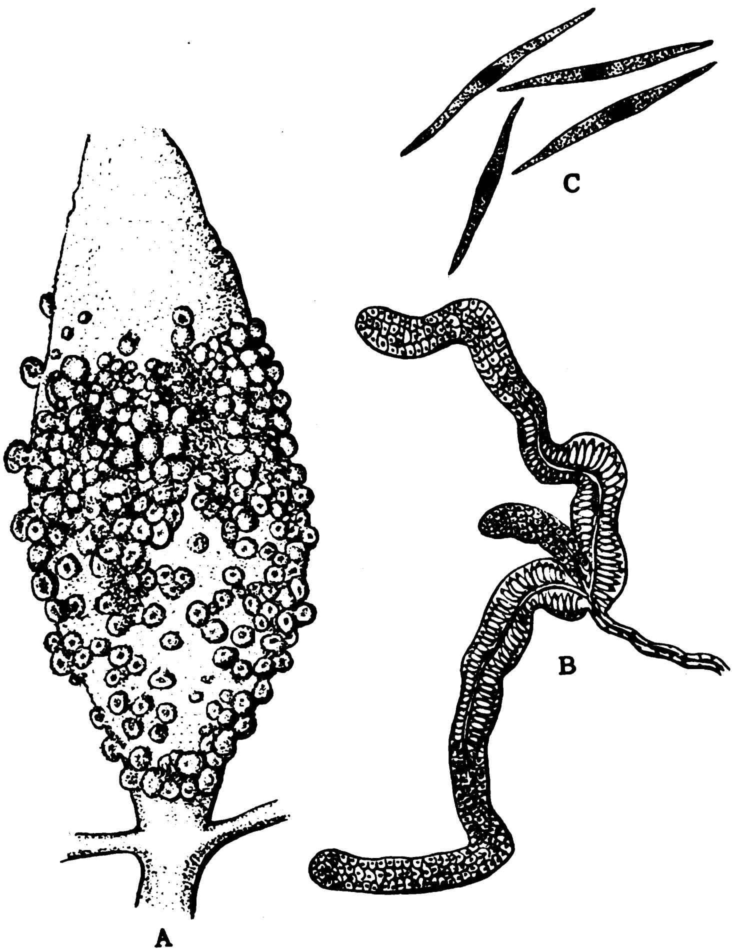


FIG. 130. A. Stomach with a heavy oocyst infection. B. Salivary gland. C. Sporozoites.

DETERMINATION OF CHLORIDES IN BRACKISH WATER

REPLACEMENT METHOD:

Equipment: Burette.
Burette stand.
Evaporating dish - 6 inches.
Brown bottle for silver nitrate.
Dropping bottle.
Graduated pipettes.

Reagents: Standardized silver nitrate solution made by dissolving 4.791 grams of pure recrystallized silver nitrate in distilled water to make one liter.
Saturated solution of potassium chromate.
Calcium carbonate.

Method: Transfer one to ten cubic centimeters (depending on amount of chloride expected) of the sample to the evaporating dish; add 100 cc. of distilled water, one cc. of the chromate indicator, and a small pinch of calcium carbonate (to counteract any possible acidity of the sample); add the standard silver nitrate solution from the burette to the stirred sample until the color changes from light yellow to pink; run a blank determination on the reagents - that is, go through the regular procedure using no sample - to determine how much silver solution it requires to produce the color change which the operator recognizes as the end point; subtract this blank from all titrations and make the following calculations:

$$\text{Parts chloride per 1,000,000 parts of sample} = \frac{\text{Corrected titration in cubic centimeters} \times 1{,}000}{\text{cubic centimeters of sample taken}}$$

Discussion: The brackish condition of water is due to the presence of salts (chlorides, bromides, sulfates, etc.). In pools where mosquitoes are breeding, the salts responsible for the brackish condition may be dissolved from the ground around the pool by leaching or may be derived from ocean water or both. In practically all brackish water situations, the halide salts (chlorides, bromides, and iodides) are present in large quantities, while the non-halide salts (sulfates and carbonates) are present in very small quantities. The determination of the halide content (which is expressed as chlorides) of a pool gives a comparative, but not absolute, indication of the brackishness of the water.

If the chloride content in a sample of ocean water is known, it is possible to apply an empirical formula and determine the total salts present. This is due to the fact that although the total salt content of ocean water varies in different parts of the world-higher in equatorial regions, lower in polar regions and on the continental shelves-the relative quantities of the component salts remain the same. The total salinity of a sample of sea water or of brackish water can be determined by the following formula:

Salinity = 0.030 plus 1.8050 chlorides in ppm.

DETERMINATION OF CHLORIDES IN BRACKISH WATER

There are only a few instances where water in a pool containing mosquito larvae would have salts in the same proportion as found in sea water. It is desirable, therefore, to express the brackish condition of water in terms of the halides (expressed as chlorides) present.

SPECIFIC GRAVITY METHOD:

Specific gravity is defined as the ratio of the weight of any volume of a substance to the weight of an equal volume of some other substance taken as a standard, the measurements being made at the same temperature. When dealing with solids or liquids, pure water at four degrees centigrade is taken as the standard and is assumed to have a specific gravity of one. In brackish water pools, the dissolved salts increase the weight of the water and, therefore, the specific gravity. It is possible then, by determining the specific gravity of a sample of water from the pool, to obtain a rough idea of the salt content. Naturally, there are severe limitations to this method, since any substance dissolved in the sample, whether chlorides or not, will affect the specific gravity.

The instrument used to measure specific gravity is known as a hydrometer. A crude hydrometer may be made by weighting one end of a stick treated to make it impervious to water. This stick will float upright at a level that is dependent upon the specific gravity of the solution in which it is placed. The stick may be calibrated by placing it in distilled water and marking it at exactly the water surface. Whenever the stick floats at this level subsequently, it will indicate that the medium in which it floats has a specific gravity of one. By placing the stick in other solutions of known specific gravities, other indicator marks may be added at the appropriate places. The type of hydrometer which is most useful in this work is the one used in clinical laboratories, known as a urinometer. This is calibrated so that it is possible to read specific gravities to the third decimal place (thousandths). A urinometer and a small graduate may be carried in the field kit, and specific gravities taken and recorded on the spot. Special care should be taken to see that the hydrometer is carefully calibrated in distilled water before use, and any necessary correction factor noted.

If the sample tested is from a pool formed from ocean water, it is possible to estimate the chloride content by use of Table III and the total salt content by the further use of the formula: Salinity = 0.030 plus 1.8050 chlorides in ppm. It must be borne in mind that this conversion is valid only in coastal areas where the salts present have their origin from ocean water. It is absolutely useless in situations such as land-locked bodies of brackish water where the component salts are in different proportions than in ocean water. Since various writers may express salinities of brackish water habitats differently - chlorides in parts per million, total salts in parts per million, per cent sodium chloride, grams of sodium chloride per liter, and as percentages of sea water - additional tables are presented to enable the investigator to reduce these readings to a common standard for work in mosquito biology.

Table I *

Per Cent Sea Water	Chloride in ppm
100	20,000
95	19,000
90	18,000
85	17,000
80	16,000
75	15,000
70	14,000
65	13,000
60	12,000
55	11,000
50	10,000
45	9,000
40	8,000
35	7,000
30	6,000
25	5,000
20	4,000
15	3,000
10	2,000
5	1,000
0	0

Table II **

Specific Gravity	% NaCl
1.00172	.220
1.00227	.292
1.00310	.400
1.00393	.508
1.00476	.617
1.00531	.689
1.00614	.797
1.00696	.906
1.00751	.978
1.00834	1.086
1.00916	1.194
1.00999	1.303
1.01081	1.411
1.01136	1.483
1.01219	1.591
1.01301	1.700
1.01383	1.808
1.01466	1.916
1.01521	1.989
1.01603	2.097
1.01685	2.205
1.01740	2.277
1.01823	2.386
1.01905	2.494
1.01988	2.602
1.02070	2.711
1.02025	2.783
1.02208	2.891
1.02291	2.999
1.02373	3.108
1.02456	3.216
1.02511	3.288
1.02594	3.396
1.02677	3.505
1.02760	3.613
1.02815	3.685
1.02899	3.794
1.02982	3.902
1.03065	4.010
1.03149	4.118

Table III

Specific Gravity	Chloride in ppm
1.001	741
1.002	1,483
1.003	2,224
1.004	2,965
1.005	3,706
1.006	4,447
1.007	5,188
1.008	5,929
1.009	6,670
1.010	7,411
1.011	8,152
1.012	8,893
1.013	9,634
1.014	10,375
1.015	11,116
1.016	11,858
1.017	12,598
1.018	13,339
1.019	14,080
1.020	14,821
1.021	15,562
1.022	16,303
1.023	17,044
1.024	17,785
1.025	18,526
1.026	19,267
1.027	20,000

Total salinity = 0.030 + 1.8050 x chlorine in ppm.

(Knudson's Formula)

* This table applies where sea water tests 20,000 ppm of chlorine.

** From Roth and Scheel Physikalisch-Chemische Tabellen - specific gravities of various concentrations of salt in sea water (at water and air temperature of 17.5°C.)

SECTION V

SUMMARIES AND KEYS

SUMMARY OF THE ARTHROPOD VECTORS OF HUMAN DISEASES

VECTOR	DISEASE	ETIOLOGIC AGENT (A) - Arthropod (P) - Protozoa (B) - Bacteria (R) - Rickettsia (Ba) - Bartonella (S) - Spirochaete (H) - Helminth (V) - Virus
CLASS MYRIAPODA		
Millipedes	: Hymenolepiasis	: Hymenolepis diminuta (H)
CLASS CRUSTACEA		
Microcrustacea	: Diphyllobothriasis	: Diphyllobothrium latum (H)
	: Dracontiasis	: Dracunculus medinensis (H)
	: Gnathostomiasis	: Gnathostoma spinigerum (H)
	: Sparganosis	: Diphyllobothrium species (H)
Crabs and crayfish	: Paragonimiasis	: Paragonimus westermani (H)
CLASS ARACHNIDA		
Mites	: Tsutsugamushi disease	: Rickettsia niponica (R)
	: Typhus fever (endemic)	: Rickettsia prowazeki (R)
	: Bertielliasis	: Bertiella studeri (H)
Ticks	: Tularemia	: Pasturella tularensis (B)
	: Relapsing fever (endemic)	Borrelia duttoni (S) Borrelia recurrentis (S)
	: Bubonic plague	: Pasturella pestis (B)
	: St. Louis encephalitis	: St. Louis virus (V)
	: Encephalitis (equine)	: Equine virus (V)
	: Russian encephalitis	: Russian virus (V)
	: Lymphocytic choriomeningitis	: Meningitis virus (V)
	: Russian tropical typhus	: Rickettsia species (R)
	: Rocky Mountain spotted fever	: Rickettsia rickettsi (R)
	: Sao Paulo fever	: Rickettsia brasiliensis (R)
	: Fievre Boutonneuse	: Rickettsia conori (R)
	: African tick fever	: Rickettsia species (R)
	: Q fever	: Rickettsia diaporica (R)
	: Colorado tick fever	: Unknown
	: Bullis fever	: Unknown

SUMMARY OF THE ARTHROPOD VECTORS OF HUMAN DISEASES

VECTOR	DISEASE	ETIOLOGIC AGENT
<u>CLASS INSECTA</u>		
Cockroaches	: Gongylonemiasis	: <u>Gongylonema</u> species (H)
	: Hymenolepiasis	: <u>Hymenolepis</u> <u>diminuta</u> (H)
	: Moniliformiasis	: <u>Moniliformis</u> <u>moniliformis</u> (H)
Assassin bugs	: Trypanosomiasis	: <u>Trypanosoma</u> <u>cruzi</u> (P)
	: Encephalitis (equine)	: Equine virus (V)
Sucking lice	: Typhus fever (epidemic)	: <u>Rickettsia</u> <u>prowazeki</u> (R)
	: Trench fever	: <u>Rickettsia</u> <u>quintana</u> (R)
	: Relapsing fever	: <u>Borrelia</u> <u>recurrentis</u> (S)
Biting lice	: Dipylidiasis	: <u>Dipylidium</u> <u>caninum</u> (H)
Fleas	: Typhus fever (endemic)	: <u>Rickettsia</u> <u>prowazeki</u> (R)
	: Bubonic plague	: <u>Pasturella</u> <u>pestis</u> (B)
	: Dipylidiasis	: <u>Dipylidium</u> <u>caninum</u> (H)
	: Hymenolepiasis	: <u>Hymenolepis</u> <u>diminuta</u> (H)
Sand flies	: Pappataci fever	: Pappataci virus (V)
	: Kala-azar	: <u>Leishmania</u> <u>donovani</u> (P)
	: Oriental sore	: <u>Leishmania</u> <u>tropica</u> (P)
	: Espundia	: <u>Leishmania</u> <u>braziliensis</u> (P)
	: Verruga peruana	: <u>Bartonella</u> <u>bacilliformis</u> (Ba)
No-see-ums	: Acanthocheilonemiasis	: <u>Acanthocheilonema</u> <u>perstans</u> (H)
	: Mansonelliasis	: <u>Mansonella</u> <u>ozzardi</u> (H)
Black flies	: Onchocerciasis	: <u>Onchocerca</u> <u>volvulus</u> (H)
Deer flies	: Tularemia	: <u>Pasturella</u> <u>tularensis</u> (B)
	: Loaiasis	: <u>Loa</u> <u>loa</u> (H)
	: Anthrax	: <u>Bacillus</u> <u>anthracis</u> (B)
Mosquitoes	: Yellow fever	: Yellow fever virus (V)
	: Malaria	: <u>Plasmodium</u> species (P)
	: Dengue	: Dengue virus (V)
	: Filariasis (Bancroft's)	: <u>Wuchereria</u> <u>bancrofti</u> (H)
	: Filariasis (Malayan)	: <u>Wuchereria</u> <u>malayi</u> (H)
	: St. Louis encephalitis	: St. Louis virus (V)
	: Japanese encephalitis	: Japanese virus (V)
	: Encephalitis (equine)	: Equine virus (V)
	: Myiasis	: <u>Dermatobia</u> <u>hominus</u> (A)

SUMMARY OF THE ARTHROPOD VECTORS OF HUMAN DISEASES

VECTOR	DISEASE	ETIOLOGIC AGENT
CLASS INSECTA		
Tsetse flies	: African trypanosomiasis	: Trypanosoma gambiense (P)
		: Trypanosoma rhodesiense (P)
Eye gnats	: Yaws	: Treponema pertenue (S)
	: Conjunctivitis	: Various bacteria (B)
House fly and other filth flies	: Typhoid fever	: Bacillus typhosus (B)
	: Paratyphoid fever	: Bacillus paratyphosus (B)
	: Bacillary dysentery	: Bacillus species (B)
	: Cholera	: Vibrio cholerae (B)
	: Amebiasis	: Endameba histolytica (P)
	: Giardiasis	: Giardia lamblia (P)
	: Balantidiasis	: Balantidium coli (P)
	: Cysticercosis	: Taenia species (H)
	: Yaws	: Treponema pertenue (S)
	: Trichuriasis	: Trichuris trichiura (H)
	: Ascariasis	: Ascaris species (H)
Various moths and beetles	: Hymenolepiasis	: Hymenolepis diminuta (H)
	: Gongylonemiasis	: Gongylonema pulchrum (H)
	: Moniliformiasis	: Moniliformis moniliformis (H)

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
VIRUS DISEASES	
YELLOW FEVER (Urban) (transmitted by mosquitoes)	
Aedes aegypti	North and South America, Africa
YELLOW FEVER (Jungle) (transmitted by mosquitoes and/or other arthropods)	South America, Africa
DENGUE (transmitted by mosquitoes)	
Aedes aegypti	Tropical and subtropical regions
A. albopictus	Oriental region
A. scutellaris and varieties	Australian region
PAPPATACI FEVER (Sand fly or three day fever) (transmitted by sand flies)	
Phlebotomus papatasii	Mediterranean region
Phlebotomus species	Asia, Africa, South America
ST. LOUIS ENCEPHALITIS (transmitted by mosquitoes and ticks)	
Mosquitoes of the genera *Culex*, *Aedes*, and *Culiseta*. Ticks of the genus *Dermacentor*	North America
JAPANESE ENCEPHALITIS (transmitted by mosquitoes)	
Culex pipiens pallens *C. tritaeniorhynchus* *Aedes togoi* *A. albopictus*	Japan

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
ENCEPHALITIS (caused by the virus of equine encephalomyelitis) (transmitted by mosquitoes, ticks and assassin bugs)	
Mosquitoes of the genera *Culex*, *Aedes*, *Anopheles*. Ticks of the genus *Dermacentor*. Assassin bugs of the genus *Triatoma*.	North America
RUSSIAN SPRING AND SUMMER ENCEPHALITIS (transmitted by ticks)	
Ixodes persulcatus *Dermacentor silvarum* *Haemaphysalis concinna*	Russia
LYMPHOCYTIC CHORIOMENINGITIS (transmitted by ticks experimentally)	
Dermacentor andersoni	North America
RICKETTSIAL DISEASES	
TYPHUS FEVER (Epidemic) (transmitted by lice)	
Pediculus humanus	Cosmopolitan
TYPHUS FEVER (Endemic) (transmitted by fleas and mites)	
Xenopsylla cheopis	Cosmopolitan
X. astia	Orient
Ceratophyllus fasciatus	Europe, North America
Liponyssus bacoti	Cosmopolitan
TSUTSUGAMUSHI DISEASE (Scrub typhus) (transmitted by larval mites)	
Trombicula akamushi *T. schuffneri*	Japan, Malay States, Sumatra
Trombicula species	Australian region

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	:	KNOWN REGION OF TRANSMISSION
TRENCH FEVER (transmitted by lice)		
Pediculus humanus	:	Europe
ROCKY MOUNTAIN SPOTTED FEVER (transmitted by ticks)		
Dermacentor andersoni	:	Rocky Mountain region
D. variabilis	:	Eastern United States
Amblyomma americanum	:	North America
SAO PAULO FEVER (transmitted by ticks)		
Amblyomma cajennense		
A. striatum	:	Brazil
A. brasiliensis		
Rhipicephalus sanguineus		
FIEVRE BOUTONNEUSE (transmitted by ticks)		
Rhipicephalus sanguineus	:	Mediterranean region
AFRICAN TICK FEVER (Tick typhus) (transmitted by ticks)		
Haemaphysalis leachi		
Hyalomma aegyptium		
Amblyomma hebraeum	:	South Africa
Rhipicephalus appendiculatus		
Boophilus decoloratus		
Q FEVER (transmitted by ticks)		
Haemaphysalis humerosa	}	Australia
Rhipicephalus sanguineus		
Dermacentor andersoni		
Ornithodorus turicata	}	Western United States
Amblyomma americanum		

DISEASES AND IMPORTANT VECTORS	:	KNOWN REGION OF TRANSMISSION
RUSSIAN TROPICAL TYPHUS (transmitted by ticks)		
Dermacentor nuttali	:	Russia
DISEASES OF UNKNOWN ETIOLOGY (these diseases are considered at this point since it is believed that they are caused by viruses or rickettsiae)		
COLORADO TICK FEVER (transmitted by ticks)		
Dermacentor andersoni	:	Western United States
BULLIS FEVER (transmitted by ticks)		
Amblyomma americanum	:	Texas
BARTONELLA DISEASES		
VERRUGA PERUANA (Oroya fever, Carrion's disease) (transmitted by sand flies)		
Phlebotomus noguchii *P. verrucarum*	:	South America
SPIROCHAETAL DISEASES		
RELAPSING FEVER (Epidemic) (transmitted by lice)		
Pediculus humanus	:	Cosmopolitan
RELAPSING FEVER (Endemic) (transmitted by ticks)		
Ornithodorus moubata *O. savignyi*	:	Africa
O. erraticus	:	Tunisia, Portugal
O. marocanus	:	Spain, Morocco
O. pallipedes	:	Central Asia, Palestine
O. verrucosus	:	Iran

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	:	KNOWN REGION OF TRANSMISSION
RELAPSING FEVER (Endemic) (transmitted by ticks)		
O. tholozani	:	Central Asia
O. rudis *O. talajae*	}	Northern South America, Central America, Mexico
O. turicata	:	Western United States, Mexico
O. hermsi	:	Western North America
O. parkeri	:	Western United States
YAWS (Framboesia) (transmitted in part by non-biting flies)		
Hippelates pallipes	:	Caribbean area
Musca sorbens	:	Africa
Muscoid flies	:	Tropical and subtropical regions
PINTA (vector unknown, *Hippelates* and *Simulium* suspected in part)	:	South and Central America, Mexico
BACTERIAL DISEASES		
BUBONIC PLAGUE (Human) (transmitted by fleas)		
Xenopsylla cheopis	:	Cosmopolitan
X. brasiliensis	:	Africa
X. astia	:	India, Ceylon
BUBONIC PLAGUE (Sylvatic) (transmitted by fleas and ticks)		
Xenopsylla hawaiiensis	:	Hawaiian Islands
Hoplopsyllus anomalus	:	Western United States
Ceratophyllus acutus	:	Western United States
C. silvantei	:	Mongolia
C. tesquorum	:	Mongolia
C. fasciatus	:	Europe and North America
Diamanus montanus	:	Western United States
Rhopallopsyllus cavicola	:	Africa
Or psylla siliantieur	:	Manchuria
O. dahoensis	:	Western United States
Dermacentor silvarum	:	Russia

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	KNOWN REGION OF TRANSMISSION
TULAREMIA (transmitted by deer flies, ticks, and possibly mosquitoes)	
Chrysops discalis	Western United States
Dermacentor andersoni	Western United States
D. variabilis	Eastern United States
Other species of ticks*	North America
Aedes and *Culiseta* species*	North America, Sweden
CONJUNCTIVITIS (Pink eye) (transmitted in part by eye gnats)	
Hippelates pusio	Florida, California
Siphunculina funicola	India, East Indies
ANTHRAX (transmitted in part by biting flies)	
Tabanus striatus	North America
Tabanus species*	Cosmopolitan
TYPHOID FEVER **PARATYPHOID FEVER** **BACILLARY DYSENTERY** **CHOLERA** (transmitted in part by contaminating, non-biting flies)	
Musca domestica Other filth flies	Cosmopolitan

PROTOZOAN DISEASES

AMEBIASIS **GIARDIASIS** **BALANTIDIASIS** (transmitted in part by contaminating, non-biting flies)	
Musca domestica Other filth flies	Cosmopolitan

* Suspected vector.

DISEASES AND IMPORTANT VECTORS	:	KNOWN REGION OF TRANSMISSION
KALA-AZAR (Visceral leishmaniasis) (transmitted by sand flies)		
Phlebotomus argentipes	:	India
P. chinensis	:	China
P. sergenti mongolensis	:	China
P. perniciosus	:	Italy, Sicily
P. intermedius	:	South America
P. longipalpis	:	Brazil
P. major	:	Greece
ORIENTAL SORE (Cutaneous leishmaniasis) (transmitted by sand flies)		
Phlebotomus papatasii	:	India
P. intermedius	:	South America
Phlebotomus species	:	Africa, Asia
ESPUNDIA (Muco-cutaneous leishmaniasis) (probably transmitted by sand flies)		
Phlebotomus species*	:	Central and South America
AFRICAN TRYPANOSOMIASIS (Sleeping sickness) (transmitted by tsetse flies)		
(A) Gambian type		
Glossina palpalis	:	Equatorial Africa
(B) Rhodesian type		
Glossina morsitans	:	East Africa
G. swynnertoni	:	Tanganyika
SOUTH AMERICAN TRYPANOSOMIASIS (Chagas' disease) (transmitted by assassin bugs)		
Bugs of the genus *Triatoma*, *Rhodnius*, *Panstrongylus*, *Eutriatoma*, *Psammolestes*	:	South and Central America, Mexico

* Suspected vector.

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	:	KNOWN REGION OF TRANSMISSION
MALARIA (transmitted by anopheline mosquitoes)		
Anopheles species (for a more detailed list of species involved see p. 102)		Cosmopolitan
HELMINTH DISEASES		
BANCROFT'S FILARIASIS (transmitted by mosquitoes)		
Culex quinquefasciatus	:	Cosmopolitan
C. pipiens	:	China, Japan, Egypt
Aedes scutellaris pseudoscutellaris	:	Polynesia, Fiji
Anopheles punctulatus moluccensis	:	Melanesia
A. punctulatus farauti	:	New Hebrides
A. subpictus	:	Orient, Dutch East Indies
A. gambiae	}	Africa
A. funestus	}	Africa
A. stephensi	:	Asia
MALAYAN FILARIASIS (transmitted by mosquitoes)		
Mansonia annulifera	:	India, Java, Malaya
M. annulipes	}	Malay Archipelago
M. indiana	}	Malay Archipelago
M. longipalpis	}	Malay Archipelago
M. unciformis	}	Malay Archipelago
Anopheles barbirostris	:	Celebes
A. hyrcanus sinensis	:	China
ONCHOCERCIASIS (Blinding filariasis) (transmitted by black flies)		
Simulium damnosum	}	Tropical Africa
S. neavei	}	Tropical Africa
S. metallicum	}	Guatemala, Southern Mexico
S. ochraceum	}	Guatemala, Southern Mexico
S. callidum	}	Guatemala, Southern Mexico

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	:	KNOWN REGION OF TRANSMISSION
LOAIASIS (Eyeworm infestation or calabar swelling) (transmitted by deer flies)		
Chrysops dimidiata	:	West and Central Africa
C. silacea		
ACANTHOCHEILONEMIASIS (transmitted by no-see-ums or punkies)		
Culicoides austeni	}	Tropical Africa
C. grahami		
Culicoides species	:	South America, New Guinea
MANSONELLIASIS (transmitted by no-see-ums or punkies and probably mosquitoes)		
Culicoides furens	}	West Indies, Central and South America
Culex species		
DRACONTIASIS (Guinea worm infestation) (caused by ingesting infested microcrustacea)		
Cyclops species	}	Africa, Asia, Europe; South America
Diaptomus species		
PARAGONIMIASIS (Lung fluke infestation) (caused by eating infested crabs and crayfishes)		
Astacus species	}	Orient, Africa, South America
Potamon species		
Other genera		
DIPHYLLOBOTHRIASIS (Fish tapeworm infestation) (caused by eating infested fish which have previously ingested infested microcrustacea)		
Cyclops species	}	Europe, North America
Diaptomus species		

SUMMARY OF HUMAN DISEASES TRANSMITTED BY ARTHROPODS

DISEASES AND IMPORTANT VECTORS	:	KNOWN REGION OF TRANSMISSION
DIPYLIDIASIS (Dog tapeworm infestation) (caused by ingesting infested fleas and biting lice)		
Pulex irritans *Ctenocephalides canis* *C. felis* *Trichodectes canis*	:	Cosmopolitan
HYMENOLEPIASIS (Rat tapeworm infestation) **GONGYLONEMIASIS** **MONILIFORMIASIS** (caused by ingesting infested species of beetles, moths, fleas, cockroaches, millipedes)	:	Cosmopolitan
CYSTICERCOSIS (Bladder-worm infestation) **TRICHURIASIS** (Whipworm infestation) **ASCARIASIS** (Ascaris infestation) (transmitted in part by contaminating, non-biting flies carrying eggs to food)		
Musca domestica Other filth flies	:	Cosmopolitan
GNATHOSTOMIASIS **SPARGANOSIS** (caused by ingesting infested microcrustacea)		
Cyclops species	:	Orient, Australia
BERTIELLIASIS (caused by ingesting infested mites)		
Orbatid mites	:	Asia, Africa, West Indies, Mauritius

ARTHROPOD DISEASES

CUTANEOUS MYIASIS (Tropical warble fly infestation) (caused by fly larvae which hatch from eggs carried to skin surface by mosquitoes and ticks)	:	Mexico, Panama, Argentina

FAMILY CULICIDAE

KEY TO THE SUBFAMILIES

ADULTS

1. Flagellum of antenna with fourteen segments; subcostal vein ending above or before the base of the radial sector (vein 2); wings without scales; mouthparts short, unfit for piercing . . . . . DIXINAE
   Flagellum of antenna with thirteen segments; subcostal vein ending much beyond the base of the radial sector (vein 2); wings with scales, at least on the wing fringe .2

2. Mouth parts short, unfit for piercing, palpi incurved; wing scales almost confined to the wing fringe . . . . CHAOBORINAE
   Mouth parts modified to form a long piercing proboscis, palpi not incurved; wing veins and legs scaly . . . . CULICINAE

LARVAE

1. Thorax narrow with distinct segmentation; prolegs on the first two abdominal segments; tracheae ending in a pair of discs on the eighth abdominal segment . . . . DIXINAE
   Thorax distinctly broader than abdomen, without distinct segmentation; paired prolegs lacking. 2

2. Antennae prehensile, with long and strong apical spines. . . . . CHAOBORINAE
   Antennae not prehensile . . . . .CULICINAE

KEY TO THE TRIBES OF THE SUBFAMILY CULICINAE

ADULTS

1. Proboscis rigid, the outer half more slender and bent backwards; a spurious vein behind the 5th vein (a single genus, Megarhinus) . . . . .MEGARHININI
   Proboscis more flexible, of uniform thickness (at times swollen at the tip), outer half not bent backwards; never a spurious vein behind the 5th vein 2

2. Abdomen without scales, or at least with the sternites largely bare; scutellum crescent-shaped, evenly setose; wings usually spotted; palpi of female usually as long as proboscis . . . . .ANOPHELINI

Abdomen with both tergites and sternites completely clothed with scales; scutellum trilobed, the setae only on the lobes; wings not spotted; palpi of female much shorter than proboscis. 3

3. Base of hind coxa in line with or above the upper margin of the metasternal sclerite; postnotal setae present (New World only) . . . . SABETHINI
   Base of hind coxa below upper margin of metasternal sclerite; pronotal setae absent . . . . .CULICINI

LARVAE

1. Without a siphon . . . . ANOPHELINI
   With a siphon (which is as long as it is broad or longer). 2

2. Mouth brushes with a few (ten) stout rakers; usually pink coloration (a single genus, Megarhinus) . . . . .MEGARHININI
   Mouth brushes with many hairs (thirty or more); pink coloration only found in one unimportant genus 3

3. Anal segment with a median ventral brush of several to many hair tufts . . . . CULICINI
   Anal segment without such a median ventral brush (New World only) . . . . SABETHINI

KEY TO THE OLD WORLD GENERA OF THE TRIBE CULICINI

ADULTS

1. Squama fringed (fringe usually complete, rarely interrupted); sixth longitudinal vein reaching well beyond the base of the fork of the fifth longitudinal vein 2
   Squama bare or rarely with one to four short hairs 15

2. Pulvilli present; pleural chaetotaxy well developed, but spiracular and post-spiracular bristles absent . . . . .Culex
   Pulvilli absent or rudimentary 3

3. Post-spiracular bristles absent; claws of female simple (except in Leicesteria and Heizmannia). 4
   Post-spiracular bristles present, even if only one or two; claws of female usually toothed; dorsocentral and upper sternopleural bristles nearly always well developed 11

4. Spiracular bristles present (sometimes only one or two) 5
   Spiracular bristles absent 6

5. Several upper sternopleural bristles; main stem-vein at base of wing usually hairy on underside . . . . Culiseta
At most, one or two sternopleural bristles; main stem-vein bare on underside (Oriental, Australasian, and one Japanese species) . . . . Tripteroides

6. Dorsocentral (on the mesonotum) and pre-scutellar bristles absent; pronotal lobes approximated (Oriental and Australasian). . . . . Heizmannia
Dorsocentral and pre-scutellar bristles well developed; pronotal lobes well separated 7

7. Post-spiracular area scaly; claws of female usually toothed; palpi of female more than half as long as the proboscis (Oriental only). . . . . Armigeres (sub-genus Leicesteria)
Post-spiracular area bare; claws of female simple 8

8. All segments of antenna of female, and last two of antenna of male short and thick; middle femora with scale-tuft (none Palearctic) . . . . Aedomyia
Antennae normal, slender; middle femora without scale-tuft 9

9. First segment of front tarsi longer than the last four together; fourth very short in both sexes (none Australian) . . . . Orthopodomyia
First segment of front tarsi not longer than last four together; fourth not shortened in the female 10

10. Proboscis of male much swollen apically, of female slightly so, or else fork of second longitudinal vein shorter than stem of the fork (none Palearctic) . . . . Ficalbia
Proboscis not swollen apically; fork of second longitudinal vein at least as long as the stem . . . . Mansonia (in part)

11. Head with numerous short hairs on vertex in addition to the oribital row; antennae thick in both sexes, not plumose in male (one species from New Zealand only, Opifex fuscus) . . . . . . Opifex
Head without hairs on vertex apart from the orbital row; antennae slender in female, nearly always plumose in male. 12

12. Eyes widely separated, space between them clothed with metallic silvery scales (Ethiopian only) . . . . Eretmopodites
Eyes less widely separated (sometimes touching), space between them not clothed with metallic silvery scales 13

13. Wing scales generally mostly narrow (when, rarely, all are broad, the claws of the female are toothed); usually a few hairs on the upper surface of the stem vein at base of wing .14
Wing scales all very broad; claws of female simple; stem vein bare . . . . Mansonia (in part)

14. Proboscis more slender, not recurved at tip in repose in the living insect; ornamentation various. Aedes
Proboscis rather stout, recurved at tip in repose in the living insect; dark species with flat scales on vertex and scutellum (Oriental and Australian only). . . . . Armigeres

15. Wing membrane without microtrichia (minute hairs) (or these only visible under a high magnification); fork of second longitudinal vein shorter than the stem of the fork . . . . Uranotaenia
Wing membrane with distinct microtrichia (visible under a magnification of x50) 16

16. Spiracular bristles absent; clypeus normal 17
Spiracular bristles present (one or more); clypeus rather small and narrow; fork of second longitudinal vein longer than the stem of the fork 18

17. Fork of second longitudinal vein shorter than the stem of the fork; several posterior pronotal bristles; wing scales normal (one species from Malaya and Borneo only, Zeugnomyia gracilis). . . . . Zeugnomyia
Fork of second longitudinal vein longer than the stem of the fork; two posterior pronotal bristles; wing scales emarginate at tips (none Palearctic) . . . . Hodgesia

18. Proboscis very hairy, much enlarged at tip (Ethiopian and Oriental only) . . . . Harpagomyia
Proboscis not hairy, rarely enlarged at tip (Oriental only) . . . . Topomyia

LARVAE

1. Anal segment with ventral brush of at least four separate hairs 2
Anal segment with one pair of ventral hairs 17
Anal segment without ventral hairs (West African sub-region, a single species, Culex moucheti) . . . . Culex (in part)

2. Eighth segment with lateral sclerotized plate, with one row of comb teeth on its margin (plate sometimes weak); mouth brushes normal 3
Eighth segment without lateral plate 4

3. Siphonal pecten present; antennae short . . . . Uranotaenia
Siphonal pecten absent; antennae large and flattened (none Palearctic) . . . . Aedomyia

4. Siphon with pecten, the teeth of which are nearly always denticulate (pecten rarely reduced) 5
Siphon without pecten, or rarely with a few simple teeth. 10

5. Siphon with several pairs of hair tufts or else very long and slender 6
Siphon with one pair of hair tufts and never very long 7

6. Mouth brushes forming matted prehensile tufts (none Palearctic) . . . . *Culex* (subgenus *Lutzia*)
Mouth brushes normal . . . . *Culex* and *Culiseta* (subgenera *Culicella* and *Climacura*)

7. Siphonal hair tuft basal in position . . . . *Culiseta*
Siphonal hair tuft near middle, often beyond 8

8. Mouth brushes forming matted prehensile tufts (not Palearctic) . . . . *Aedes* (subgenus *Mucidus*)
Mouth brushes normal 9

9. Anal segment with complete sclerotized ring (Java, a single species, *Uranotaenia ascidiicola*) . . . . *Uranotaenia* (in part)
Anal segment (except rarely) with dorsal sclerotized saddle . . . . *Aedes* and *Heizmannia*

10. Antennae short, with small simple shaft hair; metapleural plate small 11
Antennae longer, with branched hair on shaft; metapleural plate large 14

11. Metapleural hairs all short and inconspicuous (a single species from New Zealand, *Opifex fuscus*) . . . . *Opifex*
Three metapleural hairs long (normal) 13

12. Siphonal hair tuft large, as in *Aedes*, etc. 12
Siphonal hair small and simple (a single species from Malaya and Borneo, *Zeugnomyia gracilis*) . . . . *Zeugnomyia*

13. From Oriental and Australasian regions . . . . *Armigeres*
From Ethiopian region . . . . *Eretmopodites*

14. Siphonal valves highly modified for piercing stems of aquatic plants . . . . *Mansonia*
Siphonal valves not specially modified 15

15. Abdominal segments VI-VIII normally with dorsal sclerotized plates (none Australian) . . . . *Orthopodomyia*
Abdomen without plates on segments VI-VIII 16

16. Antennal tuft well removed from tip (none Palearctic) . . . . *Ficalbia*
Antennal tuft close to tip (none Palearctic) . . . . *Hodgesia*

17. Maxillae large, ending in two strong articulated horns
(Papua and Northern Australia only). . Tripteroides (subgenus Rachisoura)
Maxillae large, produced into a long non-articulated horn
(Malaya, Borneo and Sumatra, a single species, Topomyia
argenteoventralis). . . . . Topomyia (in part)
Maxillae unmodified 18

18. Ventral hair of anal segment single, abdomen without stellate
hairs (Ethiopian and Oriental only); metathorax without
long spine . . . . Harpagomyia
Ventral hair of anal segment branched. 19

19. Metathorax with long spine dorsolaterally; abdomen always with
stellate hairs, which are often very numerous (Oriental and
Australasian with one Japanese species only) . . . . Tripteroides
Metathorax without long spine; stellate hairs of abdomen few or
absent (Oriental only) . . . . Topomyia

KEY TO THE NEW WORLD GENERA OF THE TRIBE CULICINI

ADULTS

1. Anal vein (vein 6) extending well beyond fork of cubitus (vein 5);
wings with microtrichia 2
Anal vein ending opposite or basad of cubital fork; wings without
microtrichia . . . . Uranotaenia

2. Prescutellar setae and postspiracular setae absent . . . . Haemagogus
Prescutellar setae present 3

3. Postspiracular setae present 4
Postspiracular setae absent 6

4. Spiracular setae absent 5
Spiracular setae present, sometimes small . . . . Psorophora

5. Wing scales mostly narrow, or when broad, setae are present on
upper side of the base of the first vein . . . . Aedes
Wing scales broad, setae absent on upper side of base of first vein
Mansonia (subgenera Mansonia and Rhynchotaenia)

6. Lower side of base of first vein distinctly pilose; spiracular
setae present . . . . Culiseta
Lower side of base of first vein scaly or bare; spiracular setae
absent 7

7. No setae on upper side of base of first vein; wing scales broad 8
Setae present in this area; wing scales narrow 10

8. No mid mesepimeral setae; fourth tarsal joint of fore tarsus at least as broad as long . . . . Orthopodomyia
Mid mesepimeral setae present; fourth fore tarsal joint not shortened 9

9. Post marginal wing scales longer than width of anal cell; antennal joints but little longer than broad . . . . Aedomyia
Post marginal wing scales shorter than width of anal cell; antennal joints much longer than broad . . . . . . Mansonia (subgenus Coquillettidia)

10. Mid mesepimeral setae numerous . . . . Culex (subgenus Lutzia)
These setae absent or few, about three at most 11

11. Antennae much longer than length of proboscis . . . . Deinocerites
Antennae not longer than proboscis . . . . Culex

LARVAE

1. Head of fourth stage larvae elongate elliptical . . . . Uranotaenia
Head rounded or transverse, not elongate 2

2. Air tube or siphon without pecten 3
Air tube with pecten 5

3. Air tube truncated, with a saw-toothed projection for piercing plant tissue . . . . Mansonia
Air tube not so modified 4

4. Antennae small . . . . Orthopodomyia
Antennae inflated . . . . Aedomyia

5. A single paired hair tuft on air tube (rarely with additional hairs) 6
Air tube with several tufts (if obsolete, the tube is much elongated) 8

6. Head with lateral pouches, covering projections of the maxillae . Deinocerites
Without this structure 7

7. Mouth brushes prehensile, or air tube or antennae much inflated. . Psorophora
Without these peculiar modifications . . . . Aedes and Haemogogus

8. Mouth brushes prehensile . . . . Culex (subgenus Lutzia)
Mouth brushes normal, ciliform . . . . Culex

KEY TO THE GENERA OF THE TRIBE SABETHINI*

ADULTS

1. Spiracular bristles present. 2
   Spiracular bristles absent (replaced by scales); squama bare; proboscis always shorter than the length of the anterior femur; palps not exceeding the length of the clypeus . . . . Limatus

2. Squama of wing with at most four bristles; pronotal lobes touching on top; palps generally slightly longer than the length of the clypeus 3
   Squama of wing with incomplete fringe (except in T. longipes, compressum and obscurum); pronotal lobes separated and in a sub-lateral position (except in T. espini); palps always twice the length of the clypeus; large species . . . . Trichoprosopon

3. Proboscis shorter than the length of the anterior femur (except the subgenus Cruzmyia); scutellum covered with scales which do not produce a silvery reflection 4
   Proboscis much longer than the length of the anterior femur; scutellum with scales which produce a silvery reflection; antennae half or less than half the length of the proboscis; wing with narrow scales on the basal section of the fourth vein; squama bare; small species . Phoniomyia
   Proboscis a little longer than the anterior femur; scutellum with scales which produce a silvery reflection; small species. . . . . .Wyeomyia (subgenus Nunezia)

4. Pronotal lobes well developed and almost united on top; postnotum well developed taking a position almost perpendicular to the axis of the scutellum; prealar bristles absent; mosquitoes always covered with scales with intense metallic reflections; small species, except for subgenus Sabethes which are large . . . . Sabethes
   Pronotal lobes at times closely approximated on top but never with the development observed in Sabethes; postnotum normal; prealar bristles present; small mosquitoes which are dark colored and without metallic reflections . . . . Wyeomyia (except subgenus Nunezia)

* No keys to larvae of Sabethine mosquitoes are included.

With the
compliments
of the
Commanding Officer

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NATIONAL NAVAL MEDICAL CENTER
BETHESDA, MARYLAND